TREATISE

ON THE

MANUFACTURE OF GUNS

AND

TEXT-BOOK OF SERVICE ORDNANCE.

THIRD EDITION.

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EXPLANATION OF ABBREVIATIONS USED IN THIS WORK.

R.M.L.	Rifled Muzzle-Loading.
R.B.L.	Rifled Breech-Loading (early Armstrong).
M.L.	Muzzle-Loading.
B.L.	Breech-Loading.
S.B.	Smooth-Bore.
W.D.	War Department.
W.O.	War Office.
D. of A. and S. ..	Director of Artillery and Stores.
L.S.	Land Service.
S.S.	Sea Service.
R.L.G.	Rifle Large Grain (powder 4 to 8 inch mesh).
R.L.G.[2]	Rifle Large Grain (3 to 6 inch mesh).
P.	Pebble (powder $\frac{1}{2}$ inch size).
S.P.	Selected P.
P.[2]	Cubical (powder $1\frac{1}{2}$ inch size).
C.	Cylindrical (an expl. powder).
R.G.F.	Royal Gun Factory.
R.C.D.	Royal Carriage Department.
R.L.	Royal Laboratory.
R.A.I.	Royal Artillery Institution.
O.C.	Ordnance Committee.
E.O.C.	Elswick Ordnance Company.
Expl.	Experimental.
§	This refers to the paragraph in List of Changes of War Stores.
Extracts	From the Proceedings of the Department of Director of Artillery.
M.V.	Muzzle Velocity.
R.V.	Remaining Velocity.
M.E.	Muzzle Energy.
f.s.	Feet-seconds (as to velocity).
f.t.	Foot-tons (as to energy).

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Breech-loading Guns.

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PART I.

CHAPTER I.

ON METALS THAT HAVE BEEN USED FOR BRITISH ORDNANCE.

Metals used for ordnance.—Physical properties: hardness; elasticity; toughness; tenacity; tensile strength.—The lever testing machine.—Hydraulic testing machine.—Machine for the bending test.—Bronze or gun metal.—Iron.—Cast iron.—Wrought iron.—The puddling process.—Welding property.—Fibre.—Case-hardened iron.—Character and properties of wrought iron.—Steel.—Definition.—Varieties.—Table of analysis.—Manufacture of steel.—Cement. steel.—Blister steel.—Sheer steel.—Crucible steel.—Puddled steel.—Cast steel.—Table showing varieties of cast steel made in the Royal Gun Factory.—Gun steel. —Steel coils.—Steel hoops.—Tempering.—Steel *v.* iron.—Character and properties of steel.—Table for comparison of physical properties.—Tests applied to steel for ordnance in the Royal Gun Factory.

BEFORE entering upon theories in gun construction or details of manufacture, it may be desirable to mention first the metals that have been used for ordnance in the British service, and to offer a few remarks on their *physical properties*.

Only four kinds of material have been employed in this country, viz.: bronze, cast iron, wrought iron, and steel. With the exception of bronze, these are simply varieties of one elementary substance under different conditions of admixture and treatment. Metals.

The chief qualities in a metal which have to be considered in connection with ordnance, are hardness, elasticity, toughness, tenacity, and tensile strength. Physical properties.

"Hardness" is essential for the interior of a gun, that the surface of the bore may be able to stand the friction of projectiles, especially in rifled artillery. Hardness and softness in metals are of course only comparative terms; lead is a very soft metal, but a hard substance when compared with other things. Softness implies that the material will yield to a blow or compression without returning to its original form; soft metal is liable to get dented by blows and worn away by the motion of projectiles in the bore, while any tendency to destruction will be aggravated by the heat developed in firing. Hardness is specially required in a rifled gun to preserve the driving sides of the grooves. Without hardness there can be no durability; at the same time this property must be associated with toughness, for when brittleness is present (as in cast iron) the material becomes uncertain in character, and therefore unsafe for guns. Hardness.

"Elasticity" is the property of resisting permanent elongation when the material is subjected to a stress. It is measured by the ratio of the stress to the strain; that is to say, by the ratio of the tension Elasticity.

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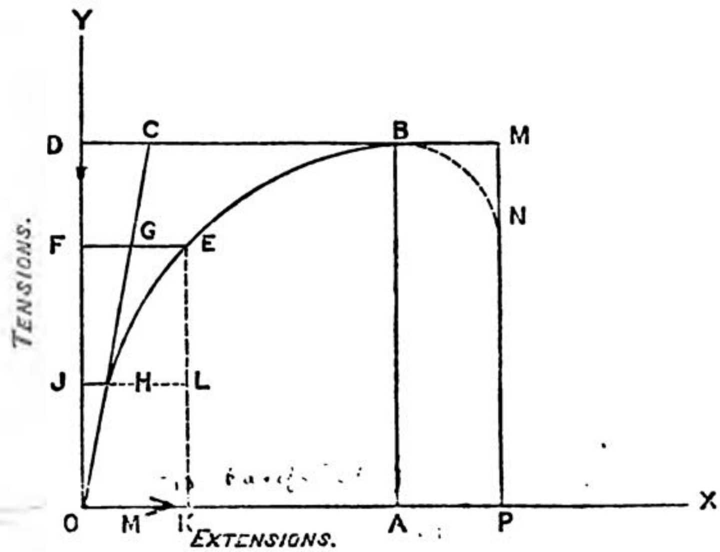
applied, to the effect of that force in producing a temporary extension which will vanish when the stress is removed.

Modulus of elasticity.

This ratio is called the "modulus of elasticity." It may be explained by the aid of a diagram :—

Take OX and OY in the accompanying figure as rectangular axes, and let the units of tension be shown on the axis of Y, and the degrees of extension on the axis of X.



Now if a specimen or bar be subjected to a regularly increasing tension, the extensions up to a certain point will increase also uniformly,* within this limit whenever the stress is removed the bar will return to its original length. The amount of elasticity will thus be shown on the diagram by a straight line such as OH, the length and inclination of which will vary with the degree of elasticity in the metal.

This constant relation of stress to strain exhibited at first is known as the "modulus of elasticity," and it may be expressed by the ratio $\frac{OJ}{JH}$, that is to say, by the cotangent of the angle JOH.

Elastic limit.

"Elastic limit" is the term to express the maximum tension which any specimen can endure without being permanently stretched. Beyond this limit the extensions will increase more and more rapidly, so that the co-ordinates representing elongation and stress will then develop a curve such as HB. For any point on this curve, a portion of its abscissa will be an approximate measure of the permanent extension, the amount being ascertained from the modulus. For instance, let a force equivalent to OF (greater than that which corresponds to the limit of elasticity) cause an extension equivalent to FE; now produce OH to intersect this abscissa in G, then FG and GE respectively correspond to the elastic and permanent extension of the bar.†

* Extension also may increase slightly in proportion to the *duration* of stress.

† Experiments have shown that the elastic limit may be raised, at any rate in the case of oil-tempered steel, by slightly stretching the specimen and giving it a permanent set. Assuming that the limit would naturally be reached under a tension of 30 tons to the square inch, 35 tons would cause some elongation or set, and this

Toughness.

Toughness is a property in metals which may be described as a strength to resist deformation and fracture either by torsion or bending. It may be associated with softness as in gun-metal, or with hardness as in tempered gun steel; and yet it is opposed to both ductility and brittleness. It is a property which will enable a bar to endure considerable distortion or curvature without yielding to reduction of sectional area at the part which is twisted or bent.

Tenacity.

"Tenacity" is a word to express the molecular strength in a metal, that is to say, its power to resist a direct tension or force tending to tear it asunder. In the foregoing diagram, suppose the point B to represent the degree of extension and force when elongation ceases in fracture; the ordinate OD is the measure of tenacity in the bar. Tenacity may embrace two elements of strength depending on the character of the metal, viz.: its elasticity and the frictional resistance to separation of its molecules. When a maximum strain has been passed a brittle specimen generally snaps without reduction of thickness; a tough specimen, however, will yield gradually to rupture, and its elongation is confined to a limited part; elasticity is first overcome, and then a narrow part is drawn out until the bar breaks at the point of smallest diameter. The tenacity per square inch of this reduced area does not diminish; on the contrary it increases largely with the frictional resistance then brought into play, until cohesion is entirely destroyed and the specimen is broken in two.

Tensile strength.

"Tensile strength" is a term which is sometimes used for "tenacity" in the sense which has just been described; it is a kindred term, but here it is intended to express a power of elongation associated with strength. It is used to denote the "work" done upon metal in effecting rupture; now "work" is represented geometrically by an area, and tenacity by a straight line, so it is necessary to adopt different terms for these different physical properties. This may be clearly explained by reference once more to the diagram.

Taking B as before for the point of rupture, the area OHBA is the measure of work expended in breaking the bar, and accordingly it represents the tensile strength of the specimen. A bar, however, will very commonly stretch after the breaking tension has been fully applied; this may be shown on the diagram by extending the abscissa DB to M. BM however, will not be a straight line (at any rate not in prolongation of DB), unless the intensity of strain is kept up in spite of diminished sectional area. Experiments with the hydraulic testing machine tend to show by mercurial indication that the ordinates for tension decrease, and therefore some curve would be formed which may be represented perhaps by BN. The co-ordinates of elongation and stress have now traced out a compound line OHBN, and the tensile strength in this case will correspond to the area OHBNP; the extent of this area will evidently depend upon elongation as well as tenacity in the bar.

Hence specimens of equal tenacity may have different degrees of tensile strength; and the metal which gives most elongation before rupture will evidently possess the greatest power of endurance. Tensile strength is especially studied in the material for guns, because,

would become a new limit of elasticity up to which the material could be afterwards strained without any further extension. The modulus is not affected by this treatment, nor is the breaking strength raised, but the limits of elasticity and tenacity are brought nearer together; the former is the real measure of working strength in a gun, so higher pressures become afterwards admissible (provided there is ample margin of strength), because no deformation will take place until the higher limit is passed.

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even under maximum strain, an accident would be avoided if rupture required a greater duration of stress than the short period a gun is kept under tension on firing.

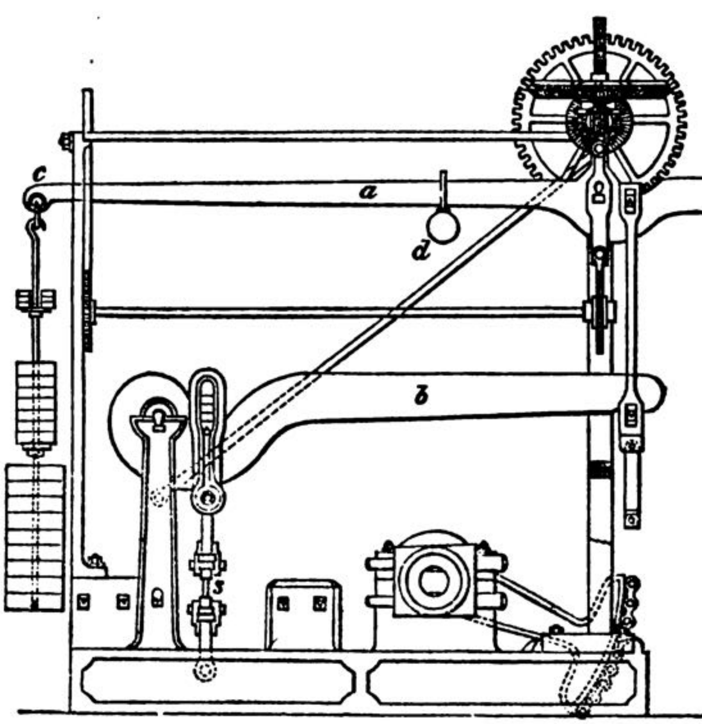
It will be seen by inspection of the diagram that the area representing tensile strength depends more on the extent of elongation than on the exact limit of tenacity, and therefore this physical property may be closely associated with ductility and softness. For example, the tenacity of tempered gun steel is fully double that of wrought iron, but the latter may show greater tensile strength. The higher elasticity, however, and strength to resist deformation of the steel outbalance the tensile advantage possessed by the material weaker in these respects. Some steel, on the other hand, though marked by extraordinary tenacity, is not a good material for ordnance on account of its brittleness; a medium quality is required, capable of receiving suitable temper, which shall have a high limit of elasticity so as to recover itself after heavy pressure in the bore, a high breaking strain so as to resist rupture, and a large percentage of elongation so as to avoid any tendency to brittleness.

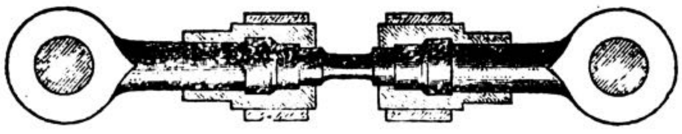
Specimens of all steel, either made in the Royal Gun Factory, or purchased by contract, are carefully tested for these chief physical properties, viz.:—Elastic limit, tenacity, elongation and toughness. The units of measurement are "tons" of tension "per square inch" of sectional area.

The Lever Testing Machine.

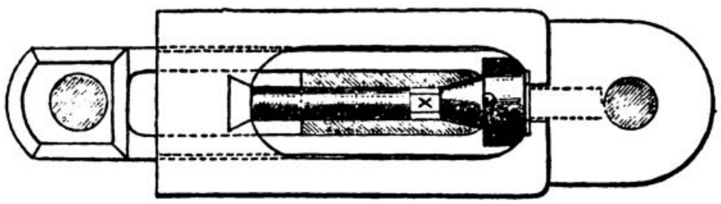
Testing machine.

The machine hitherto used in the Royal Gun Factory for testing metals was a statical lever machine; but recently a more scientific apparatus has been purchased which is worked by steam and hydraulic power. A sketch of the lever machine is given to assist explanation, but this only shows essential features without any portions of detail.





SOCKETS FOR TENSION.



FRAME FOR COMPRESSION.

It consists of a combination of levers *a* and *b* which cause a tensional stress on the specimen equivalent to a weight 200 times greater than that which is actually applied; all the bearings are hard knife edges resting on smooth steel surfaces, so that friction is reduced to a minimum. It is generally used for tensile experiments, but it can be used for compressive, transverse, or torsional elasticity, and it may also be used for experiments on the pressure required to punch or shear; or it may be adjusted for determining the hardness or softness of metals.

For tenacity. Before use, the balance of the machine must be regulated by moving the ball *d* along the upper lever, and by attaching a weight if necessary at *e*. Specimens to be tested for elastic limit and tenacity are turned down to a definite diameter, varying with the class of material, and they are furnished with shoulders to fit into the sockets at *s*. When a test piece has been placed in position, it is secured and tightened up by a wedge; weights are then gradually accumulated on shelves suspended from the point of the upper lever at *c*.

To prevent the point of this lever from drooping as the specimen stretches, and the consequent inconvenience arising from the weight not acting at right angles to the bar, there is an arrangement for raising the fulcrum to keep the top lever horizontal. The train of wheels used for this purpose also raises a frame near the point of the bar at the same rate as the fulcrum, so when the specimen breaks, the lever is prevented from flying up with a jerk which would probably injure the machine.

As the specimen stretches, a gauge may be used to ascertain the amount of extension; but when the limit of elasticity is approached, the last weight should be carefully lifted and put on again while the operator watches an index which moves with the extension and contraction of the bar.

Limit of elasticity. At this stage, when the limit of elasticity has been apparently reached, the specimen should be removed to a bench and measurements taken with a micrometer to detect the first sign of extension; much experience is required to determine this point with exactness.

When the limit of elasticity has been recorded, the bar is further tested for strength; weights are slowly added until the tension is sufficient to break it. The general character of the metal may be ascertained by this operation, for its behaviour under tension and its fracture when broken are both indications of quality. If the metal is hard it will usually exhibit high tenacity with little elongation; if soft and ductile, the extension will be considerable and the tenacity moderate.

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Some specimens will show a corrugated exterior, which is caused by the metal being drawn out more freely in the heart than on the surface of the bar; in others the flow will be uniform and smooth. Fracture, too, is a sure test character; bright crystalline appearance is always associated with brittleness, and grey silky fracture with toughness. By the inspection of a newly-broken piece any coarseness of quality may be detected; sound specimens should be drawn out near the middle of their length, and ought generally to break at the point where the diameter is most reduced.*

For compression.

For testing compressibility, a small cylinder of the metal is inserted between the jaws of a frame which takes the place of the sockets used in tensile experiments. The frame consists of two parts one sliding within the other; one part is attached to the bed of the machine and the other to the lower lever, so when weights are applied in the usual manner, the cylinder of metal is crushed up between the two slides. Time has to be considered in this case, for the amount of compression will vary to some extent with duration of stress; a 30-second sand glass is used in all cases, that the results may be at any rate comparative.

Hydraulic Testing Machine.

Maillard's testing machine.

This machine was invented by Colonel Maillard, of the French army. In general appearance it somewhat resembles a lathe; one end is fixed, and this contains an hydraulic press in a horizontal position; the other can be set at a suitable distance according to the length of the specimen. This adjustable end contains a small reservoir filled with water and spirits of wine. The bar to be tested is securely attached by strong shackles to the piston of the press at one end, and to the plunger of the reservoir at the other. The machine is put in action by a compressor, which may be worked either by a hand-wheel or by steam power. Pressure is indicated by a Bourdon gauge set immediately over the press, and another gauge in a similar manner records the pressure in the reservoir at the opposite end; these indications should be as nearly as possible the same.

By means of a copper pipe in connection with the reservoir, the amount of pressure is transmitted to a basin of mercury on a stand adjoining the machine, the spirits of wine being separated from the mercury by a diaphragm of india-rubber. The diaphragm is fixed in such a way as to render the box containing the mercury air-tight, while the mercury is in communication with a vertical glass tube which is open at the top to the atmosphere. The frame which supports the glass tube is graduated on one side with a scale of pressures, which ought very closely to correspond with those shown on the Bourdon gauge, and on the other side with a scale of tons per square inch for the tension exerted on a bar of definite sectional area.

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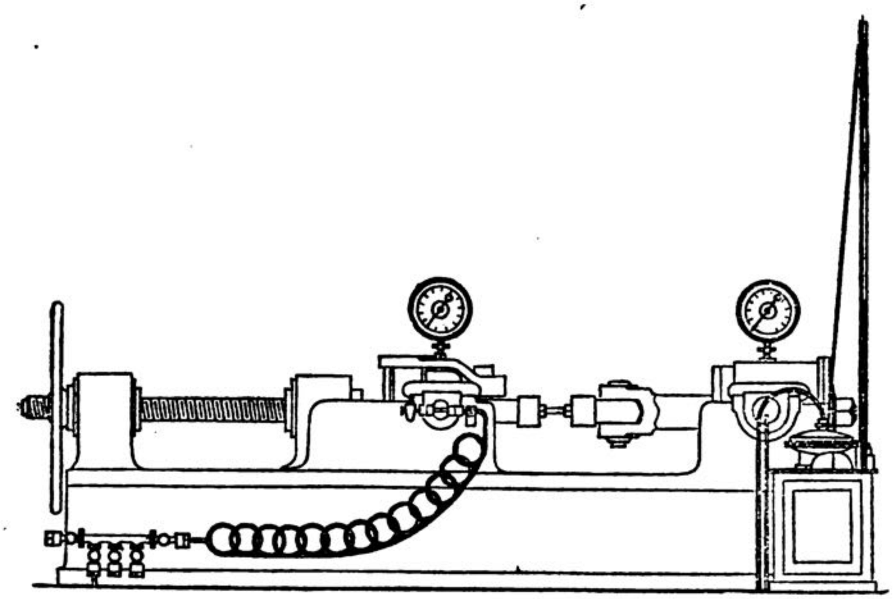
* A curious result has lately been discovered in connection with the breaking of specimens of metal, viz.: that the more rapidly rupture can be effected, the greater will be the permanent elongation of the bar. This is contrary to former notions on the subject, but experiments have established the fact. A bar suddenly torn asunder by mechanical power, such as the falling weight of a 40-ton hammer, will show greater extension than a similar piece of metal slowly tested to destruction in any statical testing machine. The agency of gunpowder is quicker than gravity or steam, and by this means the elongation has been further greatly increased. Gun-cotton, by still more rapid action, has produced the greatest elongation of all. Even hard steel has thus shown great increase of length; and it is worthy of notice in the case of both steel and cast iron, that fracture (with or without elongation), when produced by means of gun-cotton, will occur *at each end*, as if the tensile strain was felt only near the points of attachment, and the inertia of the middle part of the bar was the cause of its remaining intact.



HYDRAULIC TESTING MACHINE.

On a stand by the side of the machine, a frame may be fixed for carrying two microscopes to be brought to bear upon points previously marked on the bar. Both of these instruments are capable of being moved by slow motion screws according to the extension of the specimen, so that the moment of yielding and the degree of extension may be observed. It is a tedious operation, however, to watch for the exact limit of elasticity, and only suitable for experimental research; but the total elongation may be readily measured by the lateral separation of the instruments after careful adjustment at first.

The yielding and breaking stress can be practically ascertained by following up the column of mercury, and marking its indications with a pointer. The operation is conducted in this manner:—first, the moveable end of the machine is worked forwards by the hand wheel for insertion of the piece to be tested, then it is drawn back by the same means until a strong pull is exerted on the shackles. The pump is next set in motion and the tension begins. As the pressure on the piston increases, the mercury will rise in the tube, and the operator follows it up with a pin. When the limit of elasticity is reached, the test-piece will yield for a moment, sufficiently to affect the intensity of strain for an instant, and this causes a fluctuation which a practised man will observe; the pin is at once placed to mark the elastic limit so found, while the operator proceeds to follow up the mercury again with another. At the limit of tenacity, or highest mercurial reading, the second pin is put in, but the test-piece will not break at that point unless the metal is brittle; it will generally yield more or less slowly to rupture, and the mercury shows this by falling; continued stretching, however, must ultimately overcome the tensile strength in the bar, and on breaking, all stress is removed and the mercury subsides in a moment to the bottom of the tube.

The Bending Machine.

The bending machine in R.G.F.

This is an ingenious machine which was invented by a foreman in the Royal Gun Factory. It consists of a vertical press and two steel plates within a frame, which are placed parallel to each other, and about one

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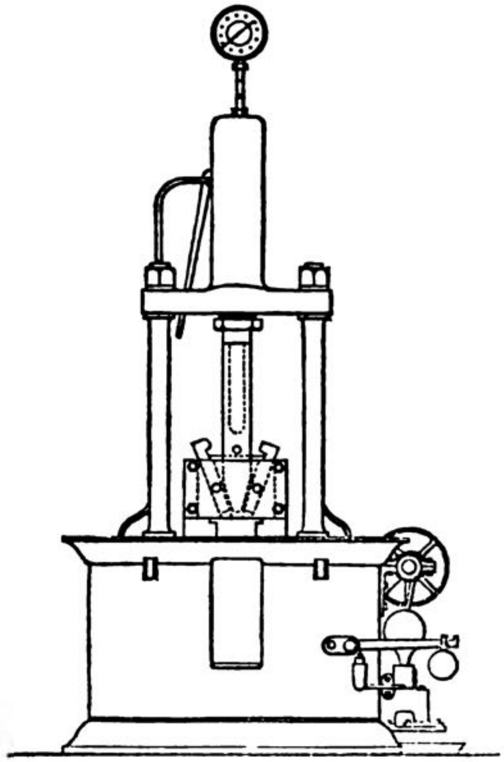
inch apart. These plates have rectangular grooves on the inside which form guides for the motion of the presser. Two rocking levers are arranged between the plates for reciprocal motion, one on each side of the central grooves; and between them is placed the flat test-piece of

Scale $\frac{1}{24}$.



HYDRAULIC MACHINE FOR TESTING SPECIMENS BY BENDING.

metal with its ends resting on shelves or recesses in the upper part of the levers. Over the middle of the specimen is fixed a presser with semi-circular end; $\frac{7}{8}$ inch in diameter for untempered pieces of steel, and $1\frac{1}{2}$ inches for those which are tempered.

The presser is gradually forced down by a block sliding in the rectangular grooves, under the ram of a hydraulic press placed vertically over it. The test-piece is in this manner bent down between the rocking levers, which close in as it yields.

Tough specimens should bend until the ends of the piece are brought parallel to each other; if brittle the specimen will break, and the angle of fracture is a measure (or at least a good indication) of brittleness. Elasticity in the metal will generally destroy the complete parallelism of the two ends after the specimen is released from the machine, especially in tempered pieces of steel.

Bronze.

Of the four classes of material that have been used for ordnance in this country, bronze was employed from the earliest days of artillery until the recent introduction of rifled guns; and although it has entirely been given up in the manufacture of *new* pieces, there are still in the service a number of small rifled guns which have been converted from smooth-bore bronze ordnance.

Bronze. Bronze is an alloy of copper and tin, and the particular sort of bronze called "gun metal" consists of 90 parts of copper, with ten of tin. It is a soft material, and liable to injury, such as indentations in the bore, drooping at the muzzle, &c., especially when heated by firing; this used often to be seen in the elliptical shape of the bore at the muzzle caused by the round shot rebounding in the gun. It is an expensive material, but tough, fusible, adapted to the old method of manufacture by casting, and easily worked in the lathe.

Tin spots. This alloy is subject to the disadvantage of never being quite homogeneous, for the points of liquation of the two metals of which it is composed differ widely. Tin melts at a temperature of 442° Fahr., but copper requires about 1,800°; consequently, after fusion and mixture, when the alloy is cooling down to a solidified state, the tin will remain liquid after the copper has set; during this period there is a tendency on the part of the tin to collect in globules in different parts of the mass. This separation of the metals not only affects the character of the alloy, but forming portions of pure tin in the casting, becomes a source of weakness in the material. Tin possesses no practical strength, and lumps of tin in the metal are little better than cavities in the mass; when these appear on the surface, or are cut through in boring, they form white patches on the yellow material and are technically known as "tin spots." They are especially injurious when found in the bore, for with the heat of firing the gas eats out the tin and converts the spot into a ragged defect; if this should occur in a rifled gun on the edge of a groove, the rifling will soon be destroyed.

Phosphor bronze. Many attempts have been made in this country, and by most of the Continental Powers, to improve the gun metal and utilise existing bronze ordnance. Small quantities of phosphorous have been added with success, and phosphor-bronze has at times given fairly satisfactory results; but this material has not proved reliable, especially in large castings, and its use was soon discontinued in England for guns.

Bronze rifled guns for India. Casting in chill has also been tried for increasing the density in order to develop strength: but no measures have met with perfect success. The last attempt in this country was made about the year 1870, when bronze 9-pounder guns were cast and rifled at Woolwich; these were intended for the field artillery in India, and some were issued to batteries at home; but, although the experimental pieces proved most satisfactory in range, accuracy of shooting, and endurance, the uncertain character of the material became afterwards apparent, and all these guns were withdrawn from the service in 1874. Bronze *smooth-bore* ordnance are retained for Reserve and Auxiliary Forces, and many pieces may be found in the armament of forts and stations abroad.

Iron.

Iron. Although one elementary substance alone exists which can properly be termed "iron," yet this metal when alloyed or associated with small quantities of other elements will form several distinct classes of

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material, which differ from one another more in their physical properties than in their chemical constitution.

These varieties may be divided into three groups; designated respectively "cast iron," "wrought iron," and "steel."

Pig iron.

Iron is extracted from its ores, in the first instance, by the process of smelting in furnaces worked either by a hot or cold blast,* and run out into sand moulds in the form of rough heavy bars; in this state it is known as "pig iron," and it contains many impurities, chiefly carbon and silicon from the fuel and flux, but sulphur, phosphorus, and other elements will generally be found by analysis.

Refined iron.

By various methods of refinery the impurities in pig iron may be removed, but some carbon will always remain, and as long as the amount exceeds 2 per cent. of the weight, the metal will possess the properties of the group which is generally termed "cast iron."

The different qualities of pig iron are distinguished in the trade by numbers ranging from 1 to 8, the lower numbers being given to samples which on fracture present a dark crystalline appearance, and the higher ones to hard and bright iron. It will be sufficient in this work to classify the varieties of cast iron by colour under three heads, viz.: "grey," "mottled," and "white."

Cast Iron.

Carbon in cast iron.

According to chemical analysis, the definition of "cast iron" is that quality of the metal which contains from about 2 to 5 per cent. of carbon, either mixed or combined with the iron.

The crystalline appearance on fracture depends mainly on the quality and condition of the carbon associated with the iron. Carbon may exist in two distinct forms of admixture: that is to say, either chemically combined as an alloy, or merely mixed with the crystals of metal in the form of pure graphite. In the latter case dark flakes are visible on a newly-broken surface, which give a grey colour to the iron; this kind is soft and fusible: when most of the carbon is chemically combined it is invisible, and the metal becomes hard, brittle, and white.

This difference in character can be produced even in specimens containing the same proportion of carbon, merely by fast or slow cooling of the metal after casting.

White iron.

White iron can always be obtained by rapid cooling, for the elements in fusion are suddenly reduced to fine crystals which present a white and glittering appearance. This is an explanation of "casting in chill," which is effected in moulds of iron instead of sand, as iron is a good conductor of heat; the heads of Palliser shot are cast in this manner, which has the effect of making them exceedingly hard.

By slow cooling or casting in sand, a large proportion of the carbon has time to *separate* from the metal, and it then appears as black flakes of graphite mixed with grey crystals of iron. Mottled iron is an intermediate quality between grey and white.

Character.

The character of cast iron may be summed up as fusible, hard, and brittle, with little elasticity or capability of extension, and with only a moderate amount of tenacity.† It is a cheap material, and easily worked into shape by casting and lathe operations; it melts at a temperature of about 1,530° Fahr. Its hardness enables it to bear a heavy

* Pig iron obtained from a cold blast furnace is worth nearly three times as much as that which is derived by the hot blast process; the latter produces a greater weight of iron from a charge, but it is mixed with impurities which have to be subsequently extracted, and refinery costs about as much as the smelting.

† About 12 tons per sq. in.

weight without yielding to compression; it is not malleable, and therefore not capable of being forged under a hammer, nor does it possess the property of welding; in fact it will break up under a blow if previously heated, and crumble into small pieces and dust.

Breaking up cast iron guns. Owing to this brittleness when heated a simple method has been adopted in the Royal Gun Factory for breaking up old cast iron guns to use the material again; condemned guns are heated to redness in any spare furnace, and then crushed into small pieces by a steam hammer.

Malleable cast iron. Although cast iron is not malleable, there is a variety known as *malleable cast iron*: this is made by a process of annealing cast iron in contact with red hæmatite ore to deprive it of carbon, at any rate on the surface of the metal. It is then in a condition to bear hammering. but it is scarcely malleable in the metallurgical sense of that word. This iron will not weld unless the metal was very pure in the first instance.

Wrought Iron.

Puddling. By complete extraction of the carbon from cast iron, the character of the metal is entirely changed; this conversion is effected by the process called puddling. The operation consists in stirring a large quantity of molten cast iron in the hearth of a reverberatory furnace, exposed to the action of heated air, so that oxygen from the draught may combine with carbon from the iron to produce carbon di-oxide, &c.; by combustion, the gases intensify the heat of the furnace and promote the chemical action, which in time burns out all the carbon and impurities from the charge. The pure iron as it "comes to nature" separates itself from the liquid in the hearth and floats in a spongy form on the boiling mass; in this state it may be gradually collected by the puddler, whose duty consists in stirring the charge, so as to bring all in turn under the action of the blast, and in balling up the pure metal into lumps of convenient size.

Shingling. When the greatest amount of iron that can be extracted from a charge has been gathered together, the slag, or tap-cinder, is run off from the furnace and the balls are withdrawn one by one; these are conveyed to a steam hammer, and all the slag that is entangled in the ball is pressed out; the metal, reduced to a solid piece of iron, is then called a "bloom."

Carbon in wrought-iron. Although the carbon is said to be removed by this process, a trace can always be discovered by careful analysis; in metallurgical works it is stated that the amount of carbon to be found in wrought iron will vary from [illegible] to 0·3 per cent.

Piled metal. Puddled blooms, which may be considered as wrought iron in its first or elementary stage, are piled together, reheated, and worked over and over again, either under a hammer or through rolling mills, to produce large masses, or bars; hence the terms "wrought iron," or "piled metal," have been applied to this class of material. The property of welding is now conspicuous, and by repetition of this process the metal is rendered fibrous and dense.

Fibre. Fibre is produced by drawing out the wrought iron at each successive operation of rolling or forging, the slabs thus drawn out being cut and piled again, with the fibre invariably laid in a similar direction. This structural character may be seen by subjecting a bar of wrought iron to the action of a powerful acid, by which the softer particles on the surface will be eaten away, and the hard fibre will then stand out clearly, resembling a bundle of wire.

The chief strength of wrought iron lies in the direction of fibre; experiments have shown that with specimens of equal dimensions it requires about twice the amount of tension applied lengthways

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with the fibre to break a bar of wrought iron as that which would be sufficient to tear it asunder transversely.

Impurities.

The quality of wrought iron is thus evidently improved by the amount of work spent upon it; but work will not remove original impurities; on the contrary, repeated forging or rolling is apt to introduce cinder and slag. Sulphur and phosphorus are impurities commonly met with, and either of these elements, when present in very small quantities, will materially affect the character of iron; sulphur renders it brittle when hot, and the term "red-short" is applied to it then; phosphorus, on the contrary, makes it "cold-short," or brittle when cold.

Red-short and cold-short.

Welding.

The property of welding is one of the chief characteristics of wrought iron. By this term is meant, that when two clean surfaces are brought in contact at a white heat (about 3,000° Fahr.) and pressed together by rolling, hammering, or any other means, the two portions will unite so perfectly that the line of junction could not be traced if the piece were afterwards cut in two. No fibre, however, can exist in the joint; so in estimating the strength of a welded bar, it is usual to take it equivalent at that point to the strength of the metal transversely. *i.e.*, half the strength of the fibrous part of the bar taken in direction of length. Welding is a most valuable property, for, since wrought iron is infusible in ordinary furnaces, it is only by welding that large masses can be obtained; and then owing to malleability these pieces can be forged into shape. Cinder or any foreign substance will prevent perfect union in welding; from this cause a mass of wrought iron will often exhibit many flaws when cut into, and it is not easy to obtain a smooth surface entirely free from defects.

Case-hardened iron.

Wrought iron is naturally soft; but if required to present a hard surface, so as to stand much friction and wear, its exterior can be hardened without destroying the general character of the bar. This is effected by placing the portion to be hardened in charcoal dust and keeping it at a high temperature for a considerable time. Carbon then passes into the iron, but only to a depth which can be regulated by the duration of the process: when treated in this manner it is said to be "case-hardened iron."

Character.

Wrought iron may therefore be described as a malleable variety of iron, containing little or no carbon, produced by a repetition of forging or rolling together. It is practically infusible, but it possesses the property of welding; it is soft, ductile, and capable of being drawn out into wire. Its limits of elasticity will range from 10 to 15 tons per square inch, and its tenacity from 18 to 25, *in the direction of fibre*; its tensile strength is remarkably good, affording great elongation between the points of yielding and rupture. As a material for ordnance it was formerly considered particularly safe under moderate pressures in the bore, but its softness and liability to defects render it unsuitable for modern artillery; its strength also and limit of elasticity are not sufficiently high for the heavy charges that are fired in the present day.

Steel.

Definition.

Steel may be either a compound of iron and carbon alone, or other elements may be associated with these two essential ingredients. Where carbon alone enters into the composition of steel, the amount may be said generally to lie between the limits assigned for its proportion in cast and wrought iron; that is to say, between 2·0 and 0·2 per cent.

it contains ·3 of carbon a little manganese & silicon

Steel guns. wanted.

Carbon in steel.

These limits, however, are not strictly correct, nor would chemical constitution alone in any case afford a satisfactory definition of steel. Specimens recently analysed have been found to contain even less than 0·2 per cent; though Dr. Percy, a most eminent authority, once fixed the proportion of carbon (when the fused metal, if free from all foreign matter, may be considered as passing from iron into steel) at something between 0·5 and 0·65 per cent. In point of fact, the line which divides steel from wrought iron cannot be traced by chemical analysis; yet these two classes of material differ very widely, both in physical properties and in their mechanical structure.

Manganese.

Cast steel now generally contains a decided proportion of manganese. Like carbon, it gives hardness to the metal, but in a less degree; it is estimated that a proportion of 0·7 per cent. manganese is equivalent in this respect to 0·1 per cent. carbon, and therefore hardness can be regulated to a much greater nicety by manipulating the quantities of manganese and carbon together than by attempting to get an accurate proportion of the latter alone.

Analyses.

The following analyses, taken at hazard, may be of interest, as showing the composition of some well-known varieties of steel recently used for the manufacture of guns. The value of the table would have been much enhanced, if comparison could have been made with samples of equal tenacity, but such analyses were not available. It must also be remembered that the composition will differ in ingots of the same class of steel even when made by the same firm; there is also frequently a marked difference between the upper and lower ends of one casting; but these examples suffice to give a general idea of the chemical components of steel.

TABLE I.

Showing the Percentage of Carbon, &c., in Steel made by different firms.

	Krupp, * tons.	Le Creusot 38 tons.	Firth, 46·3 tons.	Whitworth 45 tons.	Cammell, 53·8 tons.	R.G.F. 43·8 tons.	Remarks.
Carbon ...	·450	·381	·456	·288	·368	·291	The remainder being pure iron, with traces of sulphur and phosphorus occasionally present.
Manganese	·200	·447	·127	·404	·505	·887	
Silicon ...	·207	·094	·012	·014	·070	·024	

* The tenacity of this specimen was not known; it was supposed to be about 38 tons.

Temper.

Steel may also be described as a compound of iron and carbon which is capable of receiving different degrees of hardness and temper, by being heated and plunged into liquid, that it may cool down more or less rapidly. Pure iron is incapable of being hardened in this manner, and so is the ordinary wrought iron of the trade; as a definition, however, this will not bear application too strictly, for wrought iron may be produced of a quality that is capable of being slightly hardened, and steel may be so soft as to resemble this class of wrought iron.

Manufacture by fusion v. adhesion.

Since neither chemical analysis nor any marked physical property will furnish an exact definition for steel, we may look for a distinction in manufacture or mode of production. All steel is now made by means of some process of fusion, whereas the production of

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wrought iron may be said to depend on adhesion. This constitutes a distinction which, in discussing the materials for ordnance, it may be useful to bear in mind; but it is not a complete definition, for steel can be made without fusion.

Character.

Steels vary greatly in character, although the composition cannot evidently differ very much, and the process of manufacture may be exactly the same. Some steels are hard, brittle, and crystalline, while others are soft, malleable, silky, and ductile. Hard steels are highly elastic and strong, but the softer varieties more nearly resemble wrought iron. By careful preparation every shade of quality may be obtained between these extremes. All steel is fusible and (except very hard specimens) can be forged to a certain extent, though great care must be taken in reheating and working the metal. Its character is summed up by Dr. Percy when he states that "if carbon is present in certain proportions, the limits of which cannot be exactly prescribed, we have the various kinds of steel which are highly elastic, malleable, ductile, forgeable, weldable, capable of receiving very different degrees of hardness by tempering, and fusible in furnaces."

Striking fire with flint.

Steel heated and quenched suddenly in water should strike fire readily with flint.

Manufacture of steel.

To understand the composition of steel we must look into its history, and study some of the modern systems of production.

Steel can be made either by carburetting pure iron or by de-carburetting cast iron; it is manufactured in several ways, so as to produce a melted product for casting.

As in R. Arsenal

Krupps process

(1) By dissolving iron or steel scrap in a charge of melted cast iron, by means of an open hearth furnace;
(2) By direct fusion in crucibles of a suitable mixture of scrap, which, judging from previous analyses, will yield the right quality of metal for steel;

Sure!

(3) By reduction of pure iron ore with the proper proportion of carbon; and
(4) By blending with pure melted iron small quantities of other material which will introduce the right elements for steel.

Cement steel.

Formerly, steel was made only in small pieces suitable for tools and other requirements; the manner of preparation was known as the process of cementation, by which bars of wrought iron, containing little or no carbon, were impregnated with that element to the extent just sufficient to produce the quality of metal called steel.

For this process it was necessary to select the purest wrought iron, free from sulphur and phosphorus. Swedish bar iron was therefore generally employed, because its quality was guaranteed, both by the nature of the ore from which it is derived and by the use of charcoal in the furnaces of that country. The process of cementation consists in embedding the bars of iron in powdered charcoal in a closed chamber and maintaining a high temperature for a considerable time, so that carbon from the charcoal may be enabled to penetrate the iron, which it does in the form of carbon di-oxide; the powerful action of this gas is evident from the blistered appearance of the surface of the bars when withdrawn.

Blister steel.

Cement, or "blister," steel may be used either as it comes from the converter in malleable bars, or the bars may be broken up and melted for casting. Blister steel retains some of the properties of wrought iron, for it is capable of being raised to white heat without damage, and it can then be bent and welded together; this kind of steel is used for giving an edge to tools of large size. Or, again, it may

Sheer steel. be broken up into lengths, to be piled, reheated, and welded, when it goes by the name of "sheer steel"; this variety also has the property of standing high heat without losing its virtue, and compared with ordinary cast steel, possesses remarkable toughness and strength.

Crucible steel. To obtain larger masses of steel it became necessary to resort to casting the metal. For complete fusion a very great heat is required; cast iron will melt at about 1,540° Fahr., but steel requires at least 3,240°, and even this is lower than the temperature required for pure iron. To make crucible steel blistered bars are first broken up into lengths, which are carefully sorted according to the degree of carbon absorbed in different parts of the bar: these pieces are again broken up into very small fragments, to facilitate the process of fusion, and when preparing a charge the samples are carefully selected after chemical analysis, so as to ensure a proper quality in the steel. About 63 lbs. of metal are usually weighed out for a crucible charge, and from this, after allowing for waste, about half a hundredweight may be run out in the casting. The size of the ingot will depend upon the number of crucibles used; but when pouring out the metal it is necessary that the flow should be continuous from the start to the finish, to avoid any cooling, which would cause a defect in the steel that could not be remedied by any subsequent treatment.

Puddled steel. Balls of steel of moderate size used at one time to be made by the process of puddling, for by regulating the heat and withdrawing the ball from the furnace before the carbon has been entirely expelled, a malleable product can be obtained of the constitution required for steel. This method, however, produced highly carburetted metal which was generally uncertain in character; the size also of the blocks was limited to the weight of a ball, so this system of manufacture has now fallen into disuse.

Cast steel. There are several varieties of steel now employed in the construction of guns, most of which are associated with the names of eminent firms, such as Firth, Whitworth, and others; the systems of manufacture may be entirely different, but the products are all included under the general term of "cast steel," and they must all comply with one specification before acceptance in the Royal Gun Factory. A Bessemer retort or an open-hearth furnace may be used; the process in either case aims first at complete fusion and purification of the iron, which can only be effected by means of the most intense heat, then special ingredients are added to the molten pure iron to produce particular qualities of steel.* When sufficient time has been allowed for blending, the steel is run out into a vertical mould and cast in the form of an ingot. Care must be taken to prevent agitation in the mould, and the ingot must be allowed to cool slowly.†

Varieties of steel. To show the varieties of steel and the complete control that has been attained over its manufacture, a table is here given of eight different specimens that were made in the Royal Gun Factory in 1882 to form a standard series.

These were tested after the ordinary process of tempering in oil, and they form an interesting table, in which it will be observed that while the limits of elasticity and tenacity increase almost uniformly, the corresponding elongations decrease with equal regularity.

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* This, however, is not the case with crucible steel, for the ingredients are all previously arranged in preparing the charge.

† For a description of the Bessemer, Siemens-Martin, Basic, and other methods manufacturing steel the reader must be referred to standard metallurgical works.

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TABLE II.*

Showing results obtained with 2-inch tempered specimens of steel made in Royal Gun Factory, February, 1882.

Series.	Tension in tons per square inch. On yielding.	Tension in tons per square inch. On breaking.	Elongation per cent. on breaking.	Remarks.
A ..	21	32	32	
B ..	24	36	27	
C ..	26	39	28	
D ..	27	41	18	
E ..	32	48	18	
F ..	38	56	14	
G ..	43	62	12	
H ..	50	71	10	

Gun steel.

All ingots which are destined for parts of a gun, particularly those intended for barrels, are cast much shorter and thicker than the dimensions required for the forging. This is not alone for convenience in casting, although it is evident that a short mould can be more readily heated, moved about, and placed in a pit than a long one; the real object lies in the increase of density and strength gained by the operations of forging. The more work there is spent on an ingot in drawing it down under a hammer, the better will be the quality of the steel.

Forging steel ingots.

Great care must be taken, however, that the steel is not overheated, nor should it be drawn down very much at any one operation; cast steel will not bear to be raised to a very high temperature, for this would change its malleability into brittleness, and careless forging will often produce serious faults in the structure; in either case the material would be ruined as regards use for the manufacture of guns.

Steel coils.

Mild steel, and especially the variety known as "manganese steel," may be rolled out into bars, and then coiled and welded like iron; but the heat must be carefully watched, and it should never exceed that which is absolutely required for welding, or be kept up longer than is necessary. This was a convenient method at first for making hollow cylinders of steel for the exterior parts of large guns; the material is superior

* The following table of similar results obtained by Sir Joseph Whitworth, with his fluid compressed steel, was communicated to Captain Mackinlay, R.A., for a lecture at the Royal Artillerp Institution in February, 1884. The specimens of steel were also exhibited at the same time: they were about 6 inches long, and their ductility was remarkably good, illustrating clearly the inverse ratio that exists between elongation and limit of tenacity.

No. of specimen.	Tension in tons per square inch on breaking.	Elongation per cent.	No. of specimen.	Tension in tons per square inch on breaking.	Elongation per cent.
1	26	43	6	59	14
2	30	40	7	71	12·5
3	36	33	8	80	10·
4	39	31	9	91	8·5
5	51	17	10	100	6

to coiled iron, but it is not equal to cast and forged steel, so the manufacture has never been carried on to any very great extent.

Steel hoops.

Hoops of cast steel supply the strongest material* known, except wire; these are cut from an ingot as discs, then punched and mandrilled out into rings, or the ingot drawn out under the hammer and trepanned.

Different qualities of steel in a gun.

Different qualities of steel were at first used in different parts of a gun, but now there is only one specification for all the material employed. The varieties differed at one time both in the mode of manufacture and in their physical character; they were termed soft, medium, and high, but it is necessary to add that the terms were comparative only, and that the extremes of difference in composition and character were necessarily restricted to within very narrow limits.

Soft and hard steel.

Soft or mild steel, generally speaking, is that which contains very little carbon, is malleable, ductile, and capable of being welded. Hard or high steel has more carbon, is brittle and incapable of bearing high heat, but its tenacity and elasticity may be very great. Any steel can be drawn out into wire.

Tempering.

All steel, as mentioned already, is capable of being hardened and tempered, although very mild specimens may not suffer much alteration. The operation of tempering consists in heating the steel to a moderate degree (the temperature varying according to the quality of the metal from about 1,300° to 1,550° Fahr.), and then plunging it at once into a medium which will abstract the heat more or less rapidly. Cold water, being a good conductor of heat, will bring down the temperature quickly, and this renders the steel very hard: oil being a slower conductor is generally used to promote toughness as well as moderate hardness, and this gives the special temper required in the material for guns. The result of tempering and degree of hardness imparted, will depend very much on the amount of carbon in the steel and the heat to which it is raised; but when properly carried out, the operation of tempering has a marvellous effect in raising the elastic limit and increasing the tenacity of good steel.

Cast steel v. wrought iron.

It may be useful now to sum up the physical properties of cast steel and to contrast them with those of wrought iron, since these two materials have been extensively used in the manufacture of guns.

Steel is a fusible, homogeneous variety of iron, containing a limited proportion of carbon with usually small quantities of manganese and silicon also; it is highly elastic and strong; it may vary in quality from being brittle and hard, to malleable, ductile and tough. The softer varieties are capable of being heated and welded, but they can never possess fibrous structure to the extent developed in iron. Hard steels are entirely void of fibre, incapable of welding, brittle, crystalline in fracture, and they yield little to extension before rupture. In the

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* Experiments were carried out in 1881 to ascertain what class of material was best suited for the exterior layers on a gun. A steel cylinder open at both ends was girt in the centre by a strong band, dividing the cylinder into right and left halves: the vent and crusher gauge were also placed in this band, which was made of great strength, to prevent any failure on one side from obscuring by cracks, or in any other way, the effect on the other portion of the cylinder. The materials in competition were shrunk on at either end, right and left of the strong central band.

Shot with crusher gauges in the base were loaded at each end, and resistance was artificially increased to set up high pressures in this kind of double-ended gun. The results may be briefly stated as follows:—

(*a*) Wrought iron coils *v.* Steel coils.—The iron coils in each case expanded or failed.
(*b*) Ditto *v.* Steel hoops.—The iron coils burst explosively.
(*c*) Steel coils *v.* Steel hoops.—The coiled steel failed in each case.
(*d*) Steel hoops by different makers.—All stood the tests.

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same way that the character of soft steel may be said to approach that of wrought iron, hard steel may be taken to resemble cast iron. Medium qualities combine most of the foregoing properties in moderation and varying proportion. All steel will present a good surface, quite free from defects, and hard steel will take polish equal to that of a mirror; wrought iron, on the other hand, will always show marks of welding when the mass is cut into as by the bore of a gun, especially after erosion of gas; and this material is liable to flaws from the presence of cinder and slag, from which cast steel must of course be entirely free. By tempering, the limits of tenacity and elasticity of steel may be raised to a very great extent, being then respectively about twice and three times as high in gun steel as in the best samples of iron; and, since the limit of elasticity determines the working strength of a gun, the ratio of strength in tempered forged steel and coiled iron may be approximately stated as two to one.

Comparison of metals.

For comparison of metals that have been used in the construction of ordnance, a table is given below which shows some of the physical properties for each of the different materials; this table has been compiled from records in the Royal Gun Factory, and fairly represents the results that have been obtained in testing specimens of the metals actually used hitherto in the manufacture of guns.

TABLE III.

Showing the Elastic Limit, Tenacity, and Elongation of Metals used in R.G.F.

Revised in 1883.

Materials.	Tons per square inch at		Elongation per cent. at breaking.
	Yielding.	Breaking.	
Bronze	7	15	29
Cast iron	*	9 to 14	*
Wrought iron (in the direction of fibre)	11	22	30
Steel { untempered	13	31	28
Steel { tempered in oil..	29	43	21

The superiority of steel, both intrinsically and as material for any part of a gun, having been thoroughly established by the experiments conducted at Woolwich, the use of wrought iron was given up altogether in the year 1882: coiled steel also was superseded by cast steel forged into rings. Guns are now built up only of steel, of uniform character, cast and forged, tempered and toughened in oil. The heat for tempering has been fixed at 1,450° Fahr. $\pm$ 100°, and this is accurately obtained by means of a Siemen's electric pyrometer.

The specification for contract, and tests with which all forgings (whether destined for barrels or hoops) must be made to comply, were drawn out by the Ordnance Committee, and the following is a copy of the text.

* The specimens of cast iron were too short for the yielding point and elongation to be accurately determined.

TESTS TO BE APPLIED TO STEEL FOR ORDNANCE, ADAPTED FOR PRESENT TESTING MACHINE IN ROYAL GUN FACTORIES.

(Revised 10–11–84.)

(To be modified when larger test-pieces are adopted.)

PARTICULARS OF SPECIMENS.

From Tubes.

Each end of forgings for tubes is to be made so much longer than is needed for the length of the finished tube as to afford sufficient metal to give from the annulus between the outside of the forging and the bore of the tube (or the bore of the chamber, as the case may be), the eight specimens mentioned below, and also four spare specimens of similar dimensions, being twelve in all.

The specimens, if cut longitudinally, are to be so situated that their insides will be in line with the circumference of the bore, or of the chamber, as the case may be; and, if cut transversely, to be so situated that the middle of the length of each specimen shall be a tangent to the bore, or to the chamber, as the case may be.

From Breech-pieces or Jackets.

The end of the jacket or breech-piece which was nearest to the upper end of the original ingot is to be made so much longer than is needed for the length of the finished breech-piece or jacket, as to afford sufficient metal to give from the annulus between the outside of the forging and the bore of the breech-piece or jacket, the eight specimens required for the testing, and also four spare specimens of similar dimensions, being twelve in all; the specimens to be cut in the manner laid down for those from tubes.

From Hoops.

Hoops are to be treated as hollow forged breech-pieces,* but in cases where several hoops have been forged from one ingot, it will be only necessary to cut a ring from one end of one of the hoops; such ring being taken from the upper end of that hoop which was nearest to the upper part of the ingot.

DIMENSIONS OF SPECIMENS AND TEMPERATURE AT WHICH THEY ARE TO BE "TEMPERED."

Tensile Specimens.

Of each set of four, two are to be tested "untempered" and two "tempered."

Untempered.

The operative part of each specimen is to have, for a length of 2 inches, an uniform diameter of 0·533 inch. The enlarged ends of the specimens are to be made of a form to suit the holders of the testing machine, and are to be united to the operative part by easy curves.

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* In cases of hoops not more than 36 inches wide, it will suffice if one set of test samples be taken from either end of the hoop. The end to be selected by the testing officer.

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Tempered.

Each specimen is to be cut in a parallel cylindrical form, 1 inch diameter and 4½ inches long, then heated to between 1,350 and 1,550 degrees Fahr. (a record of the actual temperature employed being kept for future information), and plunged into a bath of rape oil having an initial temperature of 65 degrees Fahr.

When cold the specimen is to be turned to testing size.

Bending Specimens.

Of each set of four, two are to be tested "untempered" and two "tempered."

Untempered.

Each specimen is to be 4½ inches long by ¾ inch wide by ⅜ inch thick.

Tempered.

Each specimen is to be cut to a width of 1·2 inch by a thickness of 0·825 inch. It should be tempered as above described for the tensile specimens, and be reduced to testing size when cold.

TESTS.

The whole of which are to be conducted cold.

Subject to the four clauses at end of specification, the tensile specimens are to bear the following tests:—

	Yielding point, tons per square inch.			Breaking strain, tons per square inch.			Elongation not less than
	Not less than		Not more than	Not less than		Not more than	per cent.
Untempered ..	11	to	15	27	to	35	15
Tempered ..	25	to	33	38	to	48	10

The bending specimens are to be pressed flatways with a semicircular ended presser through one or more suitable apertures, furnished or not furnished with anti-friction rollers, at the option of the contractors. This test is to be borne without the steel exhibiting any indication of fracture.

	Diameter of Pressure.	Width of Aperture.
	inches.	inches.
Untempered	⅜	1¼
Tempered	1⅛	2⅜

1. In cases where the forging in its untempered state has passed the tests (with the allowance given by clauses 2 and 3), but fails to bear the required tests at either or both ends after tempering (also with the allowance given by clauses 2 and 3) at a temperature between the

limits laid down in the specification, a fresh set of samples may be taken from such end or ends of the forging and be tempered at a temperature, to be selected by the maker, but not lower than 1,200 degrees, nor higher than 1,600 degrees, all the samples comprised in one set from one end of the forging being tempered at one temperature. If the fresh set of samples fulfil the conditions, the forging may be considered to have passed the tests. The particulars of the first and second tempering should be recorded for guidance in tempering the metal for the gun.

2. In cases where the samples in the untempered state have satisfied the tests of bending and elongation, but in which the other conditions of the specification relating to the untempered metal may not in all respects have been completely complied with, and in which the samples of the same forging have satisfied all the tests in the tempered state, the forging may be considered as having passed the tests.

3. In cases where the samples from the forging have satisfied the tests for bending, elongation, and breaking, but exceed the superior limit of the yielding tests, the forging may be considered as having passed the tests.

4. The foregoing tests being made for the benefit of the Government, and not for that of the contractors, shall not relieve them from any responsibility they would be under in the absence of such tests, and shall not prevent the rejection of the steel should it be otherwise unsatisfactory.

Specimens (steel) to be marked as follows :—

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1. 2.
3. 4. 5.

1. *Part of Gun.*

A	B	b	H	J	L
A Tube.	Breech-piece.	B Tube.	Hoops.	Jackets.	Liner.

2. *Maker.*

B	C	F	G	V	W
Bolton.	Camell.	Firth.	Gun Factory.	Vickers.	Whitworth.

3. *Direction of Specimens.*

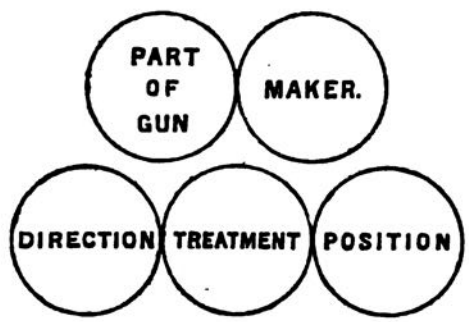
C	L	R	T
Circumferential.	Longitudinal.	Radial.	Transverse.

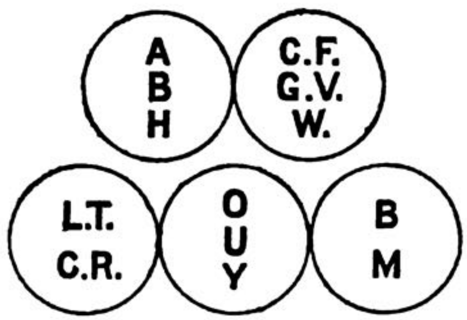
4. *Treatment of Specimens.*

O	U	Y
Oil-tempered.	Untempered.	Cut from piece tempered in mass.

5. *Position.*

B	C	L	M	U
Breech.	Centre.	Lower-end.	Muzzle.	Upper-end.





AF LUB	AF LOB	AF LUM	AF LOM
BC CUB	BC COB	BC LUM	BC LOM
HG CUB	HG COB	HG CUM	HG COM

C. Dickson, General,
President Ordnance Committee.

PART I.

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CHAPTER II.

THEORIES IN GUN CONSTRUCTION AS APPLIED TO SERVICE ARTILLERY.

Gun construction.—Forces acting within the chamber when fired.—Pressure in the bore.—Resolution of the force.—Transverse stress.—Radial pressure and circumferential tension.—Variation of intensity.—Radial transmission of strain.—Barlow's law.—Hart's law.—Rankine's formulæ.—Thin cylinders.—Ratio of thickness to internal diameter.—Thick cylinders.—Mean and maximum hoop-tension.—Curves representing pressure and tension.—Limit of pressure.—Total resistance and total strength.—Concentric hoops.—Shrinking.—Employment of mass for initial compression.—Similar annuli.—Colonel Gadolin's theorem.—Varying elasticity.—Steel barrels.—Palliser principle.—Italian guns.—Longitudinal stress.—Comparison of longitudinal and circumferential stresses.—Method of calculating strength of guns employed in R.G.F.—Service systems of construction.—Original.—Modified.—Fraser.—Marking by numerals.—Experiments and trials.—R.G.F. system.—Return to B.L. guns.—Development of power.—Steel constructions.—Cross strain near the breech-screw.—Wire guns.—Advantages in wire.—Objections.—Conditions of use.

In the manufacture of modern guns, there are many points to be considered which involve theories and calculations sometimes of a complicated nature; so in designing and working out the details of a piece, these different considerations require to be arranged for harmony and general advantage, in order that a gun of any given weight may possess a maximum power with proper facility for firing. *Principal considerations in the manufacture of ordnance.*

Gun manufacture may be said to embrace all the following questions, viz.:—

(1) Material.
(2) Construction.
(3) Design.
(4) Muzzle or breech-loading.
(5) Rifling.
(6) Firing arrangement.
(7) Sights, or means of laying, the best suited to the method of mounting.
(8) And all other matters of detail connected with the fittings on a gun.

"Material" has been discussed in the previous chapter; the next point is "construction," but neither space nor present knowledge will admit of this subject being dealt with exhaustively; an attempt, however, will be made to explain the character of some necessary investigations, and to exemplify different systems of construction by reference to the classes of guns which have been successively adopted for service. *Gun construction.*

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Gun Construction.

Forces acting within a gun when fired.

In the first place it is necessary to understand the nature and intensity of the forces which act upon a gun when fired with a heavy charge.

Pressure of the powder gas.

The origin of stress is the rapid generation of gas in a chamber of very limited size compared with the volume which the gas would occupy if unconfined. The evolution of gas is the work of a period of time, and its action upon the inner surface of a gun has been proved to possess the nature of a *pressure* and not that of an *impulse.* Instruments have been devised for measuring this pressure in the bore, so we are able to investigate the force according to the laws which govern the behaviour of a gas.

Powder-chamber considered as a closed cylinder.

For a moment after ignition of the charge, that is to say, until the projectile is well set in motion, we may consider the chamber of the gun as a closed cylinder containing gas at a very high density, which exerts a fluid pressure on the walls of this part of the gun with considerable intensity: movement in the shot (like the opening of a valve) relieves the structure which after certain progress of combustion in the charge was labouring under the full working pressure assigned to the gun.

Resolution of the force.

It is convenient for purposes of construction, as well as for theoretical investigation, to resolve the forces contained in this fluid pressure in two directions at right angles to each other, viz.: parallel and perpendicular to the axis of the piece; and then to deal separately with each resolved portion of the force in working out the construction of a gun.

Stress and strain.

These principal stresses cause corresponding tension or strain in the metal. Strain is measured by the ratio of extension to original length; and this may be estimated on the diameter of a circle as well as on the length of a straight bar. Disregarding for the present the effect upon the end of the bore, which we may consider sufficiently strong to prevent failure at that point, the stress tend, either to split the gun longitudinally in the region of the chamber, or to produce a transverse fracture between the end of the bore and some point represented by the base of the shot at the moment of maximum pressure. These two effects are commonly called the transverse and longitudinal strains.

We may assume that the strain at any part is proportional to the intensity of the calculated stress; there are no doubt subsidiary strains, but these may be neglected without appreciable error. Lamé has shown in his "Leçons sur l'Elasticité" that the principal stresses may be separately dealt with, and also that if taken together the consideration of them would lead to much complication and difficulty.

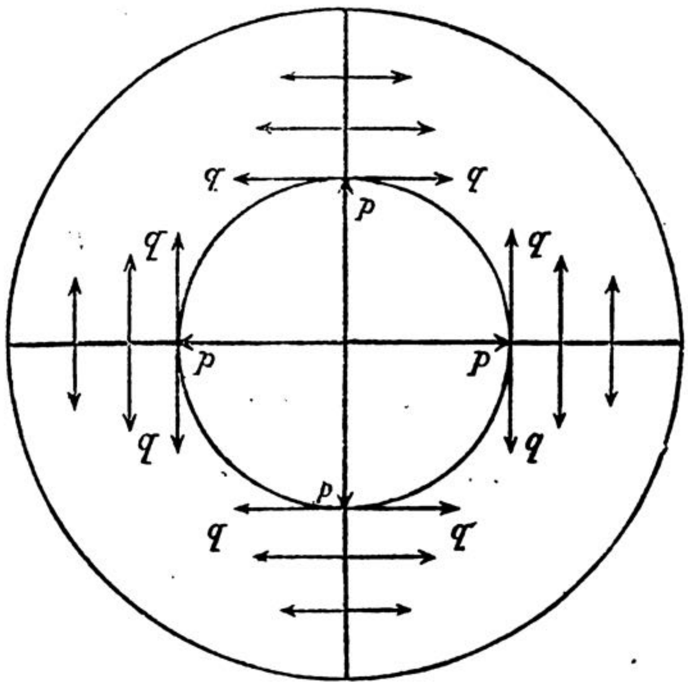
Transverse and longitudinal stress.

The transverse stress has a tendency to *burst* a gun, *i.e.*, to split the chamber in the direction of its length. The longitudinal stress tends to break open the chamber transversely. We must now proceed to investigate the intensity of force in the transverse and longitudinal directions, at different parts of the structure and at varying distance from the axis of the piece.

Transverse Stress.

Radial pressure and circumferential tension.

Taking a unit length of the chamber measured along the axis of the gun, it is evident from the figure here given that the radial pressure of the gas at any point is converted into a circumferential tension of the material, and that this force is resisted by the tangential strength of the metal.



In the days of cast-iron guns, the requisite strength was provided by increasing the thickness of metal, but no manufacturing change was adopted to regulate the strength of the material itself according to the varying intensity of strain at different radial distances from the axis of the piece.

Variation of tension. Now tension diminishes towards the exterior: for if we imagine the thickness of the metal to consist of an indefinite number of concentric rings, the tension of the innermost ring must balance a portion of the pressure of the gas, so that only a diminished pressure is transmitted to the second ring, which therefore has less tension than the first; and so on to the exterior surface. But the outer ring (in homogeneous metal) would be intrinsically as strong as the inner, so the full strength of any thickness of metal can never be fully brought into play. Considering the internal diameter constant, every additional unit of thickness with decreasing usefulness, very greatly increases the weight: so by casting alone it is evident that the strength of a gun cannot be made in proportion to its own weight. In fact, whatever may be the thickness of metal, strength is limited by the degree of tenacity in the material; for if the inner surface were to crack under pressure of gas, total failure must follow in time, and probably with explosive effect.

Objection to casting.

Radial transmission of strain. The radial transmission of strain is our first point for mathematical investigation, and this has been thoroughly discussed by many very eminent men.

Barlow's law. Treating the chamber of a gun as a closed cylinder subject to high pressure within, Professor Barlow, F.R.S., established a law that the strain at any point in the metal must vary inversely as the square of its distance from the axis of the chamber.

A simple proof of this law may be given in the following manner:—Assuming the metal to be incompressible and the time instantaneous, some expansion of the cylinder must obviously occur when the internal pressure is sufficiently high to cause any strain in the metal. Then

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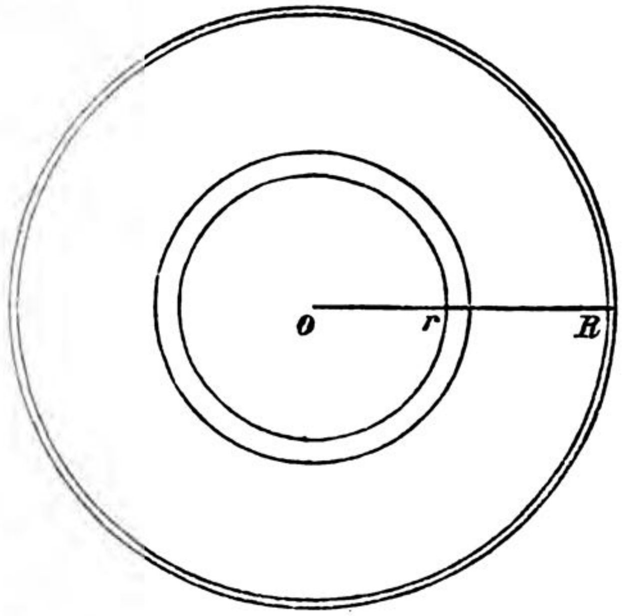
taking a right section through the cylinder, the annulus of expansion within must be equal to the annulus of expansion without. If we take



r and R as the internal and external radii of one wall of the chamber, and dr, dR as the increments of length at the moment of expansion, it follows that

$$\pi \left\{ (r + dr)^2 - r^2 \right\} = \pi \left\{ (R + d\,R)^2 - R^2 \right\},$$

and this equation becomes by reduction and neglecting the squares of differentials,

$$r \, . \, dr = R \, . \, dR,$$

from which a ratio may be obtained for the comparison of strain at the inner and outer surface of metal, viz.:

$$\frac{dr}{r} : \frac{dR}{R} : : R^2 : r^2;$$

in other words, the strain at any point in the metal, will vary inversely with the square of the radial distance of that point from the axis of the cylinder.

Hence if the strain at the inner surface be known from the pressure exerted within, say S, and σ be the strain at any point where radial distance is ρ, we obtain the general expression

$$\sigma = \left(\frac{r}{\rho}\right)^2 S.$$

But this formula is not strictly correct even with homogeneous metal, for there should be an external pressure to balance the pressure within, a condition which is seldom fulfilled; except perhaps in the case of one ring in a system of concentric hoops.

Hart's law.

Taking compressibility into account, Dr. Hart, Fellow of Trinity College, Dublin, calculated that a greater amount of tension was transmitted towards the exterior. His formula with similar notation may be written

$$\sigma = \left(\frac{r}{\rho}\right)^2 \cdot \frac{\rho^2 + R^2}{r^2 + R^2} \cdot S,$$

or for the comparison of strain on the inside and outside, when $\rho = R$ and $\sigma = s$,

$$s = \frac{2\,r^2}{r^2 + R^2}\ S.$$

It will be instructive to apply these two formulæ by way of an example to a 68-pr. cast-iron gun, in which r and R may be taken as 4 and 13 inches respectively.

By Barlow's law, $s = \frac{16}{169}$ S, or approximately $\frac{1}{10}$th of S.

By Hart's law, $s = \frac{32}{185}$ S, or approximately $\frac{1}{6}$th of S.

The difference of the formulæ is thus shown to be great; perhaps some mean is correct, but Hart's is acknowledged to be the more accurate of the two.

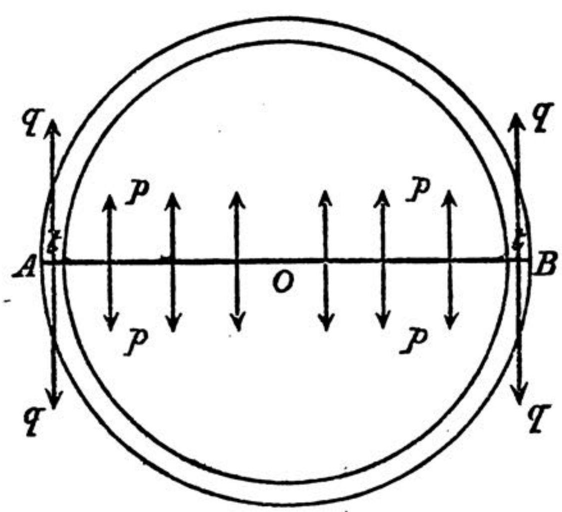
Longridge, Rankine, and Lamé.

In 1860 this question formed the subject of a paper which was read at the Royal Institution by Mr. Longridge, C.E. More recently it has been fully discussed by Professor Rankine, late Regius Professor at the University of Glasgow; and M. Lamé is a very great authority in this matter.

For a complete solution of the problem it appears that thin and thick cylinders must be separately dealt with: the former will enable us to understand the general system of investigation, but the latter present conditions which more nearly resemble a gun. Professor Rankine supplies the following method of dealing with this subject.*

Rankine's formulæ.

Taking a cylinder of very thin metal, the thickness of which t, is so small compared with the radius r, that the strain may be considered as uniformly distributed throughout, and considering one unit of length



* See Rankine's "Applied Mechanics."

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Thin cylinder.

measured along the axis of the cylinder; the tendency to rupture in any plane AB is due to the fluid pressure p per unit of area acting over the internal diameter; and the strength to resist rupture is the tenacity of the two walls of metal t, t. The tension therefore upon the ring at any point is equal to the pressure multiplied by a semi-diameter; and for its intensity q we obtain the expression

$$q = \frac{pr}{t}.$$

This is the force per unit of length tending to split the cylinder lengthways.

Ratio of thickness to internal diameter.

By substituting in this equation the full tenacity of the metal in lieu of the tension applied, we arrive at the ratio of thickness to semi-diameter when the pressure is on the point of bursting the cylinder, viz.:—

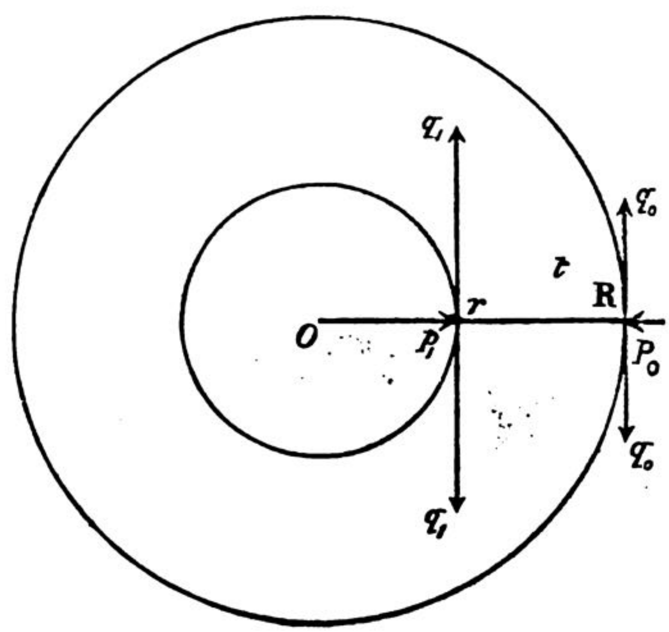
$$\frac{t}{r} = \frac{p}{f}.$$

Thick cylinder.

These formulæ may now be applied to a *thick* hollow cylinder, in which the circumferential tension cannot be considered uniformly distributed through the material.

Mean-hoop tension.

The *mean* hoop-tension in a series of imaginary rings, of a total thickness represented by t, is given as before by the expression $q = \frac{pr}{t}$; but it is not mean but the *greatest* tension (that is, the



tension round the inner surface) which is limited by the strength of material. So we require to investigate the law of variation of tension, and to ascertain the relation which the maximum bears to the pressure within.

General solution.

For a general solution it must be supposed that there is a pressure outside as well as the pressure within—it only becomes insignificant at the exterior of a gun

Then let r and R, in the accompanying figure, be the internal and external radii; p_1 and p_0 the pressure per unit of area within and without; and q_1 q_0 the hoop-tensions at the inner and outer surfaces of metal.

Now consider as before one unit of length measured on the axis of the cylinder: a radial section of that ring has to sustain the difference between the total pressures from within and without, that is $p_1 r - p_0 \text{R}$.

Conceive this ring to be divided up into an indefinite number of hoops, each of the thickness dr, and exerting a tension of intensity q; then the total hoop tension will be $\int_r^{\text{R}} q\, dr$; and it follows that

$$\int_r^{\text{R}} q\, dr = p_1 r - p_0 \text{R} \quad . \quad \quad . \; . \; . \; \text{(A)}$$

From the symmetry of the ring and the nature of the forces acting upon it in all directions round the centre, it is clear the axes of stress of any particle of metal must be respectively in the direction of the radius and perpendicular to that direction; that is to say, we have at any point a radial pressure p varying in intensity from p_1 at the inner surface to p_0 at the outer; and a hoop-tension q also variable from q_1 to q_0 in proportion to the intensity of p.

We may consider each of these principal stresses to be made up of two component pairs, viz.:

A pair of equal stresses of the same kind whose common intensity, stated so as to be a tension when positive and a pressure when negative, may be represented by the expression $\frac{q-p}{2} = m$: and a pair of equal stresses of contrary kinds, whose common intensity is $\frac{q+p}{2} = n$. Hence $q = n + m$ and $p = n - m$.

The problem will have to be solved by considering each of these cases alone, and afterwards combining their effects; but only the solutions of equation (A) are admissible which are true for all values of r and R.

Taking the first case alone; then $n = o$, and $q = m = - p$, which shows that instead of a pressure a radial tension exists, which is equal to the hoop-tension of intensity m. Equation (A) is fulfilled by making m constant (k) which reduces both sides of the equation to $k\,(\text{R} - r)$.

In the second case $m = o$; then $q = n = p$; and the solution of equation (A) is arrived at by making $q = p = n = \frac{c}{\rho^2}$, where c is an arbitrary constant, and ρ any value of the radius from r to R: for this reduces both sides of the equation to $c \left\{ \frac{1}{r} - \frac{1}{\text{R}} \right\}$.

Combining the two partial solutions we find that:

$$\left.\begin{array}{l} \text{The radial pressure } p = n = m = \frac{c}{\rho^2} - k \\ \text{and the hoop tension } q = n + m = \frac{c}{\rho^2} + k \end{array}\right\}$$

These equations for tension and pressure can be represented by curves; for taking the centre of the bore as an origin of co-ordinates, pp and qq can be drawn according to the ordinates obtained from the

Curves for pressure and tension.

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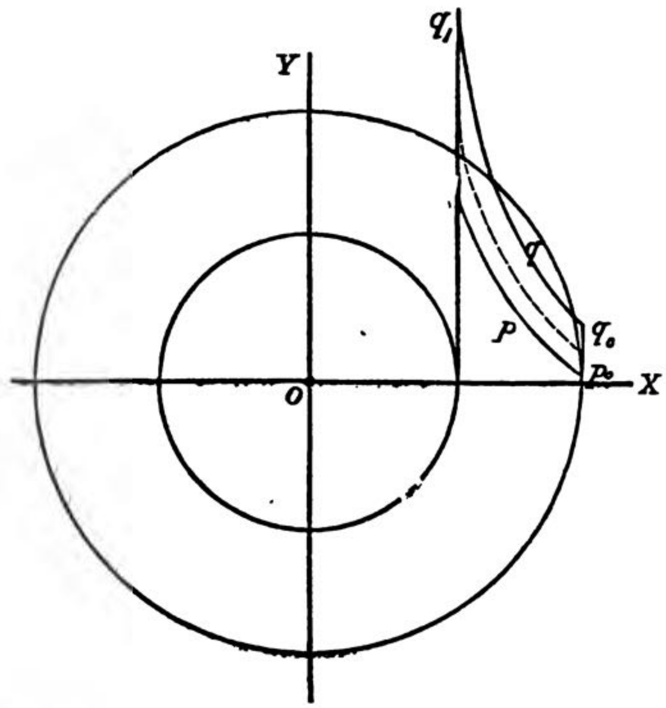
equation $y = \frac{c}{x^2} \pm k$. If the value of k be ignored the curves are



identical, and the pressure and tension become apparently equal. This would be an illustration of Barlow's law, which asserts simply that the strain varies inversely as the square of the distance; but it is also strictly correct according to the more accurate theories of Lamé and Rankine, when the internal and external pressures are inversely proportional to the squares of the radial distances of the surfaces to which they are applied.

To determine the constants c and k, we have the equations $\frac{c}{r^2} - k = p_1$ and $\frac{c}{R^2} - k = p_0$; whence

$$c = \frac{(p_1 - p_0) R^2 r^2}{R^2 - r^2}$$

$$k = \frac{p_1 r^2 - p_0 R^2}{R^2 - r^2}$$

Maximum hoop-tension.

giving as a maximum hoop-tension, when $q_1 = \frac{c}{r^2} + k$, as follows:—

$$q_1 = \frac{p_1 (R^2 + r^2) - 2 p_0 R^2}{R^2 - r^2} \quad . \quad . \quad . \quad \text{(B)}$$

Now the mean hoop-tension is $\frac{p_1 r - p_0 R}{R - r}$; and this is exceeded by the maximum in the proportion of $\frac{p_1 (R^2 + r^2) - 2 p_0 R^2}{(p_1 r - p_0 R)(R + r)}$ an expression which tends towards equality as r and R become more nearly equal.

A similar expression can be obtained for comparison of the mean with the minimum; so we have arrived at a law regarding the transmission of strain, and the application of this law to the chamber of a gun will depend upon the values which may be assigned to the internal diameter, the thickness of metal, and the pressure of gas in the bore.

Limit of pressure.

By a transposition of the equation for maximum tension we can obtain a ratio between the external and internal semi-diameters, when the tension would be just sufficient to cause rupture: the hoop-tension (q_1) would then be as great as the tenacity of the material (f), and $\frac{R}{r} = \sqrt{\frac{f + p_1}{f - p_1 + 2 p_0}}$. Neglecting the external pressure, which is comparatively small, this ratio may be written $\frac{R}{r} = \sqrt{\frac{f + p}{f - p}}$.

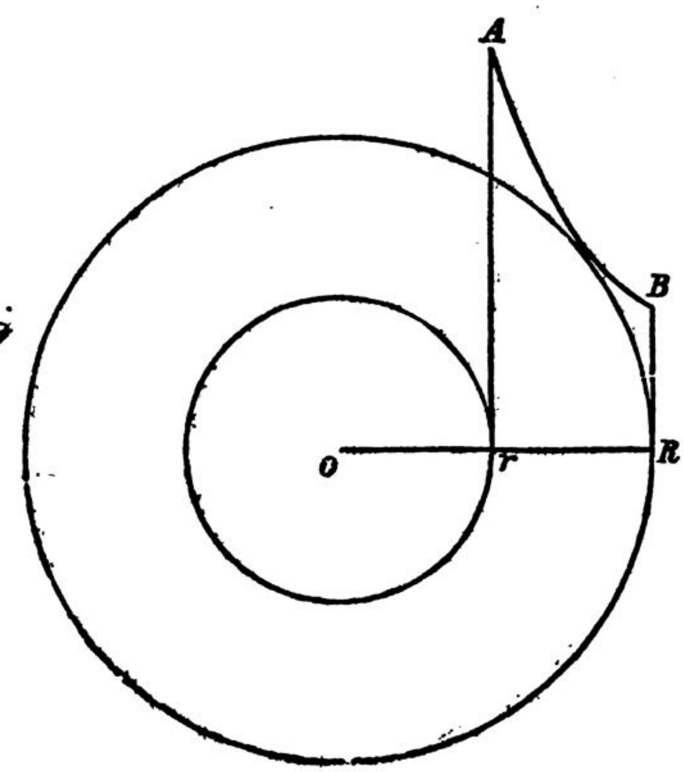
Hence *if the pressure becomes equal to, or greater than, the tenacity of the metal, no thickness, however great, will enable the chamber to resist that pressure.*

Total resistance to rupture.

We can now find the total resistance which any hollow cylinder would offer to a pressure within, and compare this working power in the metal with the total strength of the wall, supposing that all the strength in the thickness of metal could be brought into play.

Taking any radius O r R, draw ordinates rA and RB to represent the intensity of strain according to the value of n, or $\frac{c}{\rho^2}$.

Then r A : RB : : R^2 : r^2,



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and A and B are points in a hyperbola of the second order. Draw the curve, and if Ar is taken as equivalent to the tenacity of the material, the area $rABR$ is evidently a measure of all the resistance that can be offered by the whole thickness of metal.

Let E represent this area or measure of useful effect, then

$$E = \int_r^R \frac{c}{x^2}\, dx = c\left(\frac{1}{r} - \frac{1}{R}\right)$$

$$= \frac{c}{rR}(R - r).$$

Now the whole strength of the metal could only be brought into play on the supposition that the tension was uniformly distributed throughout, and equal to the ultimate tenacity of the metal. The resistance then would correspond to $\frac{c}{r}$ (R − r). Comparing this total strength, which we will call S, with the actual resistance E, we obtain the ratio—

Ratio of total resistance to strength.

$$\frac{E}{S} = \frac{\frac{c}{rR}(R - r)}{\frac{c}{r^2}(R - r)} = \frac{r}{R}$$

Deductions.

From this we may draw two deductions: firstly, that the thinner the wall, the more nearly E approaches the value of S, and the greater the proportional amount of work done by the metal; secondly, that the greater the value of r, or calibre of a gun, the more advantageously can thickness of metal be increased.

Construction with concentric hoops.

To obviate as far as possible the unequal distribution of strain, and to increase the strength of that part which has to endure the maximum stress, guns have been built up of late on various systems of concentric hoops; the outer hoops being *shrunk* on in succession to support and compress the interior, and so strengthen the inner metal beforehand to meet a greater stress than it otherwise would be prepared to withstand. Within a certain distance of the bore the material should thus be placed in a state of initial compression, and beyond this distance in a state of circumferential tension. This tension of outer material grips the inmost cylinder of metal, and transfers some of the exterior strength towards the surface within, where the greatest strain will be felt.

In the earliest forms of construction, and in the wire gun, an attempt was made to build up very numerous laminæ of metal, so that on applying a particular internal pressure, a uniform tension would be developed throughout.

If this idea could be strictly fulfilled, every part of the gun would take an *equal* share of the strain; but perfection cannot be attained. Thin hoops expanded by heat for the purpose of being shrunk over a tube are liable to be held in a state of extension without exercising compression at all, and tension of this kind is weakness. Experience has shown that the full benefit of compression cannot be obtained without the employment of *mass*; and the mass of each hoop must be sufficient to dominate over the rigid resistance of all the metal within.

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Shrinking.

By shrinking heated rings of suitable size on the core of a gun, and allowing them to cool and contract in position, a statical force is called into existence sufficient to compress the metal immediately surrounding the bore. This firm grip must be first overcome before the compression is changed into tension, and thus a large share of the strain is thrown upon exterior metal which otherwise might be only dead-weight. No strength of material is exactly created, but a force is brought into play by the hoops under shrinkage, which must be neutralised by some of the pressure within before any strain can be felt, and then only a reduced stress is left to attack the metal under its normal condition of elasticity and molecular strength.

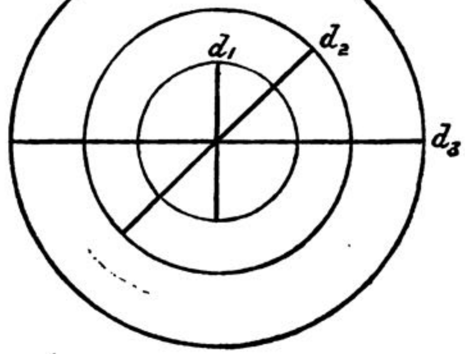
Employment of mass.

The system of building up a gun in this manner was employed first by Sir Wm. Armstrong at Elswick, to whom we are indebted for the earliest rifled guns in the service; but the adoption of *mass* as an essential condition in this concentration of strength was an improvement introduced in the Royal Gun Factory. No formula for thickness of rings can be given which would be applicable to all guns that have been made during the last twenty-five years; but, speaking approximately, the thickness of exterior coils of wrought iron has been generally arranged so that a section through the breech of a gun should present a series of *similar annuli*.

Similar annuli.

The exact dimensions have been determined by special consideration of each case, so that as an absolute rule similarity in the rings has seldom been strictly produced; for primary calculation however the relative thickness of any two layers may be ascertained from the ratio

$$d_1 : d_2 : : d_2 : d_3$$
$$\text{or } d_2 = \sqrt{d_1 \times d_3}$$



Colonel Gadolin's theorem.

This method of calculation agrees with the theorem which has been attributed to Colonel Gadolin, of the French Army, viz.:—That the maximum strength of a gun built up in tubes of the same kind of material, is obtained by making the semi-diameters of the exterior surfaces increase in geometrical progression.

Compression and tension.

In a system of concentric tubes, thus built up by shrinking one over another, the outer tube will evidently be left in a state of tension, and the inner tube in a state of compression; while any middle portions should be in compression with regard to the tube next outside, and in tension with regard to the next tube within. The radial pressure of the gas through any such system will of course be continuous from

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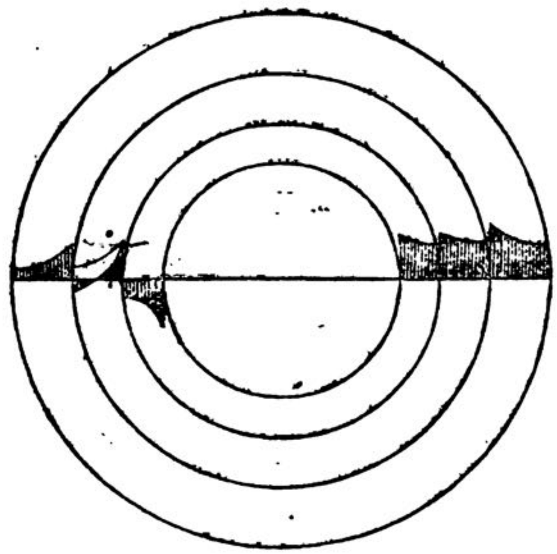
within to without, subject only to the law of diminution for distance; but in passing from one tube to another there must be discontinuity in the hoop-tension. This point has been fully explained by Professor Greenhill in a recent investigation for the Ordnance Committee.

Initial compression.

In the diagram herewith, initial compression is shown by negative, and tension by positive ordinates; the curves on the left are intended



to represent their relative values according to existence in a state of repose, and the curves on the right the alteration supposed to take place when an internal pressure is applied. Compression ought then to be entirely changed into tension, and all the tensions should be increased.

Varying elasticity.

We come next to a principle in gun construction which is supplementary to that of initial compression, viz.: the combination of different metals in different parts of a gun, the elasticity of which should be proportional to the intensity of strain.

Elasticity is the real limit of strength, and not the tenacity of the metal; for if permanent extension begins to take place, the material is weakened, and expansion may be followed by consequences of a serious nature. A combination of metals with this object in view has been termed a principle of "varying elasticity," and accordingly we find that steel and wrought iron were combined in the manufacture of guns.

Steel barrels.

Steel barrels were first introduced merely as a lining for wrought-iron guns to obtain a hard surface in the bore, more durable than iron, and more free from defects; but steel happens to possess much higher limit of elasticity than iron, with only a small degree of extension under high tensile strain. This strong material, when placed in proximity with the maximum stress, absorbs a large share of the strain; and although introduced as a mere lining at first, it really brought a new principle into construction. The elasticity of the steel near the surface of the bore balances a large proportion of tension on firing, and the small expansion of the tube transmits a small pressure to the next layer of weaker material.

Limits of application.

Both these principles, viz., initial compression and varying elasticity, must be exercised within definite limits. "Initial tension" must never exceed or even too closely approach the limit of elasticity in the metal; for if the gun should be subjected to an abnormal stress, that

limit might be passed, and the hoop would be permanently stretched. In such a case varying elasticity might prove to be a source of risk; for if the hoops on a gun were expanded while the barrel returned to its original size, the latter would be left unsupported. The steel would probably expand again up to the iron, but the gun might also be said in a way to have no greater strength than that of the barrel itself. So an excessive pressure in the bore, which might not apparently damage the gun or cause any visible injury, would render the piece unsafe for the future. The jacket alone might be strong enough to meet the contingency of possible failure within, but exterior strength would only prevent an explosion; a cracked barrel must render the gun quite unserviceable, though further rounds might be fired without necessarily causing an accident.

Palliser principle.

With this danger in view, the late Sir Wm. Palliser urged that the more ductile metal should form the interior lining, and he applied this suggestion to a combination of cast and wrought iron. A barrel of the softer material would of course maintain touch with a rigid exterior case; but this combination is based on ductility and relative strength, rather than upon varying elasticity in the two descriptions of iron. It was adopted as a measure of economy for the conversion of existing cast iron ordnance, and not for the manufacture of new guns. As regards permanent contact this principle appears to be sound, but a combination of steels would be found more effective, with the advantage of initial compression.

Italian guns.

The Italian Government have tried making guns of cast iron and steel, shrinking hoops of the latter upon a body or core of cast iron. This is just the reverse of the Palliser system; for a hard and unyielding interior is supported by the tension of hoops, instead of a soft barrel being expanded to contact with a brittle and unyielding case. A hard surface is given to the bore by cast iron, and its hardness may help to transmit pressure to the strained rings of steel, while incapability of extension to any degree must ensure permanent contact. Guns of this kind are comparatively cheap, but power is sacrificed to price, and the system requires to be proved. A 100-ton gun has been made on this plan, and it has passed through some trials to the satisfaction of those who designed it. Modern slow-burning powder will contribute towards its chance of success, but cast iron is a weak and treacherous metal, and the strength of a gun of this kind must depend on the support which it gets from the hoops; by substituting a core of tough steel for one of cast iron, we unite the Italian and Palliser systems, and approach the most modern construction.

Two lessons have been learned from experience in varying elasticity: one, that if the support of the inner barrel depends on the tension of hoops under shrinkage, ductility must be avoided in the outer material, although a certain power of elongation is desirable as a proof of the absence of brittleness; the other, that recovery after expansion (if not equal in the different hoops) should be quickest in external rings, to preserve contact throughout the period of stress, and avoid the dislodgment of any part of the gun by a continued pressure at the end of the bore while the grip of the hoops is relaxed.

Longitudinal Stress.

Longitudinal stress.

The second principal stress on a gun when fired, is the force acting upon the end of the bore which tends to break the breech portion transversely between this point of application of the force and the

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base of the shot, wherever that may be, before sufficient movement of the latter in the bore has had the effect of reducing the pressure and consequent strain on the gun.

In muzzle-loading guns built up with solid-ended steel tubes and a thick jacket of welded wrought iron, the end-strength was naturally great, and this point received little attention. In breech-loading guns, however, and in any system of construction employing steel hoops which cannot be united firmly together in the direction of length, longitudinal strength becomes a question of primary importance. The calculations are more simple than in estimating tangential strain, for any variation of tension in the thickness of metal may be generally speaking neglected.

Formula for intensity.

The force tending to produce rupture longitudinally is the unit of pressure multiplied by the sectional area of the bore, viz.: $p \times \pi r^2$ Considering this to be uniformly met by the whole annulus of metal $\pi (R^2 - r^2)$ the intensity of this tension is measured by the expression $\frac{p \times \pi r^2}{\pi (R^2 - r^2)}$.

Comparison of longitudinal and circumferential strain.

By comparison of this expression for longitudinal tension with the formula for greatest hoop-tension (when the external pressure is ignored), we obtain a ratio between the circumferential and longitudinal strain; thus:—

$$C : L :: \frac{p(R^2 + r^2)}{R^2 - r^2} : \frac{pr^2}{R^2 - r^2}$$
$$:: R^2 + r^2 : r^2$$

In one calibre of thickness (when $R = 3r$) this ratio would become 10 to 1. But the intensity near the surface of the bore longitudinally as well as transversely must be greater than that which is transmitted through a large mass of metal; so this comparison would be accurate only when dealing with very thin tubes. If R is taken as equal to $\frac{3}{2} r$, the ratio becomes 13 : 4. This shows that an ordinary steel barrel in wrought iron guns is subjected to a stress about three times as great circumferentially as in a longitudinal direction.

Method of Calculating Strength of Guns.

The foregoing principles are practically applied in the R.G.F. as follows:—

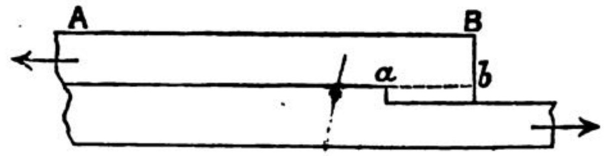
Longitudinally.

The longitudinal strength is considered separately from the circumferential, and is specially provided for by "shoulders," the *resistance to shearing* of which constitutes the longitudinal strength as calculated. No account is taken of frictional grip due to shrinkage, for it is considered as extremely probable that at the critical moment this becomes loosened by the elasticity of the different layers asserting itself more rapidly towards the interior as soon as the highest pressure has passed, while there is still a considerable longitudinal strain. Be this as it may, however, it is considered inadvisable to rely upon shrinkage in any way for longitudinal strength, and, consequently, any strength in this direction derived from the frictional grip will be in addition to the calculated strength.

The strain sustained by a shoulder is taken as a purely shearing one, and the strength of a shoulder is consequently dependent on its length; shearing strength, like resistance to tension, being directly proportional to the extent of surface where separation would take place. These strengths are also here taken to be *equal* (in tons per

square inch), which, if not strictly true, is rather in favour of the shearing strength.

The calculation, therefore, of length of shoulder for a given hoop is simple. For if AB is the supporting hoop, of internal and external



radii r, R and length of shoulder ab ($= l$ say), it is only necessary to make the cylindrical area of $ab =$ the annular sectional area of the hoop, or—

$$\pi(R^2 - r^2) = 2\pi r l$$

$$i.e., \quad l = \frac{R^2 - r^2}{2r}$$

The actual longitudinal strength of this arrangement would appear to be—

$$\pi(R^2 - r^2)\,T$$

$$\text{or} \quad 3\pi r l\,T$$

T being the resistance to rupture by tension or shearing in tons per square inch of material where separation would take place. But of course this is not strictly true, for the strain is not uniformly distributed throughout the thickness of the hoop. It may fairly, however, be said to represent the strength of the *shoulder*, and this will at all events not be *less* than that of the hoop, and the strain is transmitted from the interior outwards in precisely the same way as when frictional grip alone is relied on.

For *circumferential* strength the formula employed is— Circumferentially.

$$P = \left(\frac{R^2 - r^2}{R^2 + r^2}\right)(T + p) + p, \qquad ((B.)\text{—p. } 30)$$

the nomenclature for any hoop being—

P = internal pressure.
p = external „
R = external radius.
r = internal „
T = maximum strain (in tons per square inch) to which the material is subjected.

When there is a series of concentric hoops shrunk together these are numbered 1, 2, 3, &c., from the interior outwards, and the formula applying to each similarly numbered to prevent confusion. Thus, for the n^{th} hoop from the interior—

$$P_n = \left(\frac{R_n^2 - r_n^2}{R_n^2 + r_n^2}\right)(T_n + p_n) + p_n$$

Inasmuch as the external pressure on one hoop is necessarily equal to the internal pressure on that next outside it we must have the p of one formula dependent on the value of P belonging to the hoop shrunk over it, so that—

$$p_1 = P_2$$
$$p_2 = P_3$$
$$\vdots$$
$$p_n = P_{n+1}$$

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until we get to the outside hoop of all, where the external pressure becomes that due to the atmosphere, and may be considered as *nil*, so here p becomes 0.

The above formula, of course, gives the relation connecting internal pressure and the strain put upon the material, and is practically employed to calculate the internal pressure a given combination may be subjected to, without exceeding a fixed limit of strain on the material. The value of T has been fixed for all cases by experience at the following values, as representing the elastic limits of the materials mentioned.

For

Steel	A tubes unlined	15 tons per square inch.
	" lined	18 "
	Breech-pieces, hoops, &c.	18 "
	Steel coils	15 "
Wrought-iron coils		9 "

The steel is all tempered or oil hardened, and it will be observed that these values are much below those required by contract for specimens, the latter being—

	Elastic Limit.	Breaking Strain.
For untempered steel	11 — 15	27 — 35
" tempered "	25 — 33	38 — 48

The explanation is that the tempering in large masses is not so active in its effect as when only a small piece is treated. Again, when the surface is subjected to local destruction, as in the case of the unlined A tube, where erosion by the powder gas takes place, a considerable deduction has to be made from the strength otherwise assumable. It must be remembered, however, that there is a considerable margin of safety between the so-called elastic limit and the point of rupture, though this margin may, under certain circumstances, be reduced. Experiment has gone to prove that if the original elastic limit is exceeded it does not necessarily mean a permanent weakening of the material, though permanent extension may take place, but rather a readjustment of the elastic limit, this having been raised to the point where the strain stopped. For, in order now to produce a further permanent extension this strain must in its turn be exceeded when a fresh adjustment of elastic limit will ensue, and so on until the breaking strain is reached, when rupture will inevitably take place, no matter what the previous steps may have been. The point apparently being that the breaking strain is a definite limit, which no lesser strain will affect one way or the other. The elastic limit, however, is subject to variation, and it is well not to exceed it if the material is to retain its form and if the margin between the stretching and breaking points is to be preserved.

In the case of "liners," no strength is accredited; for, being put in without shrinkage, they are taken as so much packing, and their effect as regards calculation of strength might be ignored but for the fact that they distribute the strain to a larger area, and, consequently, its value *per square inch* is altered. Of course here, as in the case of shrinkage friction with reference to longitudinal strength, any circumferential strength derived from the "liner" will be in addition to that calculated for.

If P_1 represents the internal pressure on a liner, and P_2 that transmitted to the interior of the A tube, and r_1 R_1 the respective radii, the formula for distribution of strain due to liner is therefore simply—

$$P_1 = P_2 \frac{R_1}{r_1}$$

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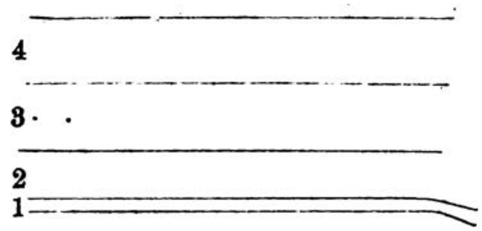
To illustrate the application of the above methods we may take an imaginary example. Suppose a gun constructed sectionally as in the figure—



1 being a "liner" of radii, 5 and 6 inches.
2 a steel A-tube of radii, 6 and 10 inches.
3 a wrought-iron coiled breech-piece, radii 10 and 20 inches.
4 a coiled steel hoop, radii 20 and 30 inches.

It is required to find the pressure per square inch that can be applied in the powder chamber without exceeding the elastic limits as laid down for the various materials.

Commencing with 4 we have—

$$P_4 = \left(\frac{30^2-20^2}{30^2+20^2}\right) 15 = 5{\cdot}77 = p_3$$

$$P_3 = \left(\frac{20^2-10^2}{20^2+10^2}\right) (9+5{\cdot}77) + 5{\cdot}77 = 14{\cdot}63 = p_2$$

$$P_2 = \left(\frac{10^2-6^2}{10^2+6^2}\right) (18 + 14{\cdot}63) + 14{\cdot}63 = 29{\cdot}99$$

$$P_1 = P_2 \frac{6}{5} = 35{\cdot}99 \text{ tons,}$$

the pressure per square inch allowable in the powder chamber.

As a matter of precaution, no gun is allowed to be subjected to the full amount of a strain thus calculated, the charges being so arranged that the pressure shall not exceed two-thirds of this, so that under ordinary conditions the elastic limit of no part of the material may be reached or permanent extension take place.

Systems of Construction in Service Artillery.

Service systems of construction.

There are several classes of M.L. and B.L. guns in the service, made at different periods in the history of rifled artillery, which in a greater or less degree embody the foregoing principles of manufacture.

Original system.

The earliest is known as the "Original," or "Armstrong construction," for we are indebted to Sir William Armstrong, of Elswick, for the first rifled guns in the service. This system consisted of forming a barrel or tube of coiled iron, made up to the required length by uniting short welded cylinders together, over which a solid forged breech-piece was placed, to provide end-strength in the gun, while over all from breech to the muzzle wrought iron coils were successively shrunk, to give the requisite strength transversely. In adopting wrought iron as a material for guns much gain was secured in tensile strength, compared with the strength of cast iron, which was the metal previously used; the fibre in the iron was disposed so as best to meet the strain in a gun; and the method of shrinking was introduced both for increasing the strength and for building up guns of large size. The several portions, however, were united by shrinkage alone, so that

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friction was an element in the longitudinal strength of these guns. The material, too, though possessing higher tenacity than cast iron, was soft and ductile; but the charges were not sufficiently heavy to give rise to much permanent expansion, and the projectiles, being coated with lead, were not of a nature to cause much injury in the bore.

Forged iron barrels.

The difficulty of manufacturing sound barrels of coiled iron led subsequently to their being made by the process of forging in one solid piece, which was afterwards bored out for a tube. These solid-forged barrels presented a clean surface in the bore, but half the tangential strength of this quantity of metal (and that too is the most important part of a gun) was sacrificed by the change. Longitudinal fissuring also became quickly apparent, and this tended further to weakness and to shorten the life of a gun. Forged barrels were therefore soon discontinued.

Steel barrels.

Steel tubes were next used, for the sake of strength, hardness, and freedom from flaws, without any change in construction. These, at first, in experimental guns, were closed at the breech end in the same manner as wrought iron barrels. Then solid-ended steel tubes were proposed and finally adopted for service; but the production of steel was then scarcely matured; steel barrels were expensive and the metal uncertain, so for several years this material was considered under probation.

Modified system.

Both M.L. and B.L. guns were made in this manner; but changes were suggested in the Royal Gun Factory, which led to another class of ordnance being built up on what may be termed a "modified system." Bars of larger section were coiled by means of more powerful machinery, so that the thickness of each coil was increased and the number of pieces in a gun were diminished. Hook-joints also were introduced to add to the longitudinal strength. But the chief feature perhaps was the welding of the trunnion ring to the breech coil, now sufficiently thick for this purpose, so that no separation could take place between the end of the bore and the trunnions which hold the gun to its carriage, without rupture of a great thickness of iron, and the bulk of the metal was thus made available to meet both the principal strains in a gun.

Fraser system.

This system, however, proved to be only a stepping-stone to a better method, suggested by the late Mr. Fraser, M.I.C.E., Deputy Assistant Superintendent of the Royal Gun Factory. He instituted the manufacture of double and triple coils, which were formed by winding a second and third iron bar of increasing magnitude over the helix made by the first; the whole mass was then welded together at single heat to form a solid cylinder of iron. In this way coils of great size were easily made, and economy was effected in labour and cost of the guns. The forged breech-piece was altogether abandoned, and all the metal over the breech of the tube, including the trunnion ring and another coil in front of the latter was worked up into one massive portion, which was then known by the name of a "jacket." This practically was a coiled iron gun, soundly welded together, without lines of least resistance for fracture, and the steel barrel was treated as a mere lining within; the jacket was strong enough in itself to prevent explosion by bursting, even in the event of failure of the steel tube.

Marks.

These three systems of construction, the Armstrong, the Modified, and the Fraser, were applied in rapid succession to all guns then under manufacture, from the 64-pr. of 64 cwt. to the 9-inch weighing 12 tons. Guns made on these different systems were afterwards distinguished by numerals stamped on the left trunnion, and designated respectively Marks I, II, and III. The Marks, generally speaking

however, must not be taken to imply any system of construction: they merely indicate the first and subsequent patterns of any nature of ordnance, ammunition, or store.

Experiments for testing the strength of construction.

The strength of the two latter systems was proved and compared by the trial of some heavy R.M.L. guns about the years 1865–6. Amongst these experiments two 64-pr. guns were tested to destruction: one was known as the B pattern (now called the Mark II) and the other was of Fraser construction (Mark III), but both had inner barrels of coiled iron. Two thousand rounds were fired with service charges from each gun without failure. Then increased charges were used, and the B gun after 2,270 rounds burst into 38 pieces; the Fraser gun failed after 2,211, the greater part of the inner tube being driven forward out of the gun, but the breech and exterior coils remained perfectly sound. In this case it was reported that, if a detachment had been standing round at the time no one would have been hurt; for the failure was merely a disruption of the barrel, from want of longitudinal strength, owing to the tube being made of coiled iron.

Shortly after this experiment steel barrels were definitely adopted, but this change in itself was not considered sufficient to involve an alteration of Mark. The thickness of steel was a point to be determined by further experiment, as explained just below.

R.G.F. system.

With increase of size another change in construction took place, which arose partly from the practical difficulty of dealing with very great weights, and partly because it was evident that the advantage of initial compression was not being fully applied.

The jacket in 25-ton guns had become a ponderous and unwieldy mass, and its very thickness suggested a division into two layers. The triple coil was accordingly exchanged for two double coils; the inner one forming a *breech-piece* and the outer one a jacket as before; but in the restoration of a breech-piece it must be observed that, unlike the portion which bore the same name in earlier guns, it was now made of *coiled* iron.

Experiments for construction and thickness of steel tube.

In 1869 experiments were conducted with two 9-inch guns, which included both a test of this new construction and the thickness to be given to the steel tube. In the new gun, or Mark IV, the barrel was 2 inches thick, reinforced by two double coils; the other had 3 inches of steel, supported by one triple coil, which represented the Fraser construction. The tube in the latter case was split at the 1,008th round, but the new gun survived the ordeal. The result in both cases, however, was considered quite satisfactory, because the steel tube which failed yielded gradually; and the strength of the jacket was thoroughly proved by firing 41 rounds after the barrel had split, and still the exterior remained perfectly sound.

Decision.

Both guns, in fact, had behaved so exceedingly well that it was difficult to decide which pattern should govern manufacture; eventually it was settled to make no alterations in guns of 8-inch calibre (or less), but for 9-inch and upwards the thinner steel tubes were adopted with two coils of wrought iron over the breech. The jacket was afterwards divided into three instead of two parts, by separating off the smaller coil in front of the trunnions; this further change was desirable on account of increasing length and the difficulty which was experienced in shrinking on to the gun a portion of variable thickness.

Parts of an R.M.L. gun.

The parts of a heavy R.M.L. gun were then six in number, viz: the barrel, breech-piece, B coil in front of the trunnions, B tube over the muzzle and chase, the jacket, and a cascable screwed into the breech to support the end of the barrel. This for the sake of distinction may be called the "R.G.F. system"; it was retained for very many years,

read ...

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and most of the muzzle-loading guns of 9-inch calibre and upwards have been built up in this manner.

Return to a B.L. system. In 1879 the reaction took place which brought about a return to breech-loading guns, but this did not at first create any change in the material, or in the construction of ordnance; so we find that some breech-loading pieces were built up of wrought iron and steel in a similar manner to the latest R.M.L. guns. The length had begun to increase, and dimensions must naturally affect the construction; but a great change was at hand, and B.L. guns of new type have now little in common with any of the muzzle-loading guns in the service.

Power of modern ordnance. In 1881, after full trial, the manufacture commenced of this new class of ordnance in which power has been developed to a remarkable degree. Estimated by the energy imparted to a shot, the power of a modern breech-loading piece (weight for weight) is nearly double what it was in the days of muzzle-loading guns.

Causes of the development. This development of power may be attributed to some or all of the following causes, viz.:—(1) change in material; (2) increase of length; (3) the adoption of large powder chambers; (4) the use of more elongated projectiles; (5) a new system of rifling; (6) nature of the powder and density of the charge; and (7) careful regulation of resistance in the bore.

Steel core. This progress in the power of artillery, though rapid, was brought about by degrees; the use of more steel was first urged, as being a better material than iron, more highly elastic and doubly as strong. So we find that the barrels increased both in length and diameter, until the lining of steel was changed into a steel body or core for the gun; and the coils of wrought iron diminished to a corresponding extent.

Steel coils. Steel coils for exterior cylinders were next introduced, made from bars of mild steel coiled and welded like iron. Large hollow cylinders of steel could be easily formed in this manner with existing machinery, but the gain in strength did not prove to be nearly as great as that obtained with solid forgings of steel, so the latter in turn superseded steel coils.

Steel hoops. Experiments were then undertaken to ascertain by practical means the exact material best suited for exterior hoops; these have been already described,* resulting in a triumph for steel, particularly steel cast and forged; so it was decided in 1882 to adopt steel altogether, according to a design which was brought forward by the Superintendent R.G.F. as a type: the steel to be cast, forged, and mandrilled out into hoops, and then shrunk over a barrel of steel, which is cast and forged from a very thick ingot to the required dimensions and length.

Accordingly wrought iron has been quite given up in the manufacture of guns, but it must still be employed in the repair of those which have been made to former designs.

Steel construction. With the use of steel hoops, a new departure was taken in the method of building a gun. In the first place it was no longer possible to obtain longitudinal strength, as in the case of wrought iron, by welding the cylinders end to end; and secondly, the degree of shrinkage most suitable for steel proved to be very different from that which had been formerly given to iron.

Shrinkage. The question of shrinkage was practically worked out by experiments on unserviceable barrels, the amount being increased with different hoops from $\frac{d}{1,000}$, which was the extreme limit for fibrous wrought

* See Chapter I, p. 17.

iron,* to $\frac{d}{200}$, which proved to be too great an extension for steel. As a result of the trials it was found that about $\frac{d}{500}$ gave the most satisfactory support; and this shows that the permanent extension of a steel hoop may be two or three times as great as that which was given to a wrought iron coil.

Co-efficient of expansion.

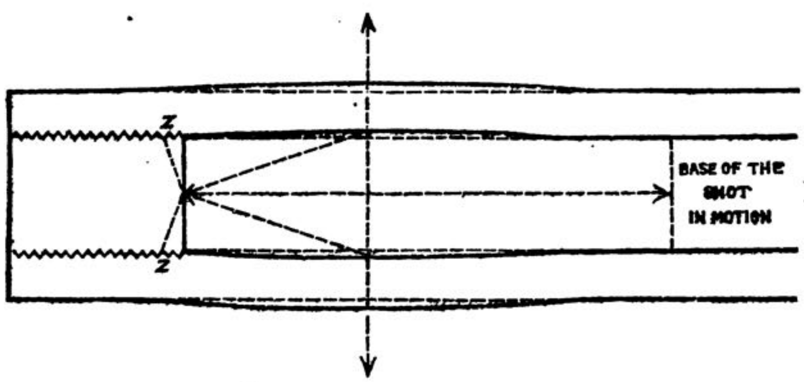
The co-efficient of expansion by heat for iron and steel being nearly the same, viz., about ·0000075 for each degree Fahrenheit, it follows that greater heat is required for the temporary expansion of a steel hoop than was formerly required for wrought iron coils; heat is liable to affect the quality of the steel, so great care must be exercised in the operation of shrinking; the exact heat will lie between 600° and 700°, and this heat may be recognised by the blue colour of the metal which is seen on scraping the surface. This temperature is not sufficiently high to injure the steel; for in tempering the metal more than double that heat was employed: it may have a slight annealing effect, but not sufficient to deteriorate the steel; on the contrary, annealing in oil is supposed to do good, and this plan is now generally adopted in the preparation of each part of a gun.

End-strength.

As regards change in construction, the barrel extended at first from muzzle to breech, and the breech screw was made to gear into the barrel. The external metal was then shrunk on in hoops till the transverse strength was complete, but the longitudinal strength of the gun depended mainly on the end-strength of the core: shoulders were duly arranged to prevent any displacement of the barrel from the trunnion ring which holds the piece to its carriage.

Cross-strain near the face of the screw.

In this mode of construction it is plain that on firing the gun the metal in proximity with the face of the screw must be subject to the maximum strain, for the longitudinal stress naturally is greatest in the region of the screw-threads nearest the end of the bore, and the circumferential tension there (if not quite a maximum also) is aggravated by a torsional stress from the expansion of the middle part of the chamber. Professor Greenhill has shown that this deformation may be exhibited in an exaggerated way by the accompanying figure and that



a tendency to rupture exists in a transverse plane, represented approximately by the points ZZ. A rigorous solution, however, of this tendency to bulge and the investigation of its effect are beset with great analytical difficulties. Curves of pressure must evidently exist, and one or two failures at proof seem to indicate that a special provision ought

* $\frac{d}{2{,}000}$ was commonly given.

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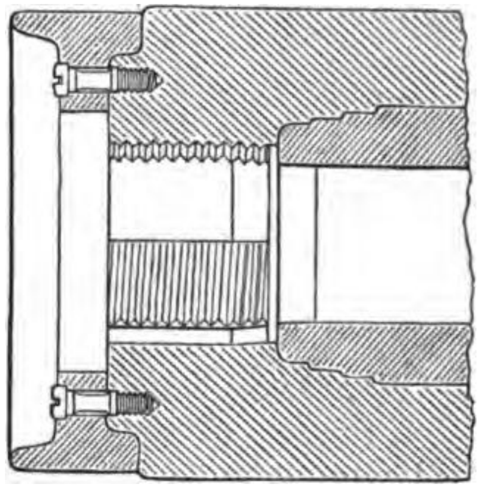
to be made to meet the intensity of stress in this part, which is rather complex in character.

Breech-screw removed from the barrel.

The breech-screw was accordingly made to gear into a breech-piece or second layer of steel to relieve the barrel altogether of stress in the direction of length. The form of the breech-piece or jacket was adapted to this change in construction; the inner diameter at the breech end being contracted by steps corresponding to steps on the barrel to avoid any sudden change in the thickness, and the barrel was made to end on a level with the face of the screw. The obturator alone was permitted to enter the bore, so that all cross strain was abolished, and the longitudinal stress on the core was reduced to the frictional pull of the pad during the highest pressure of gas.



Breech-piece, or Jacket.

The breech-piece in the heavier guns is a cylinder of steel, made in the same manner as the barrel itself, differing only in length and diameter; there are various ways of linking this part of the gun to the trunnions, while it may be supported by exterior hoops to complete the requisite strength transversely. In the lighter natures of ordnance the trunnions are forged on the ingot which forms this part of the gun, and it is then known by the name of a "jacket."

Among the latest improvements, however, and amongst those of greatest importance, is a plan of uniting all parts of a gun together by a system of bayonet joints.* The jacket or breech tube in this case is prepared at one end with a row of projections on the inner surface, while the body of the gun is prepared in like manner with a corresponding row of projections without; in the operation of shrinking (*i.e.*, in building up of the gun), the projections on the one part pass between those on the other; the outside portion is then turned round in position until they engage one another. All the intervals are afterwards filled up by wedges driven in very tightly; one wedge would be sufficient to key up the parts, but by placing them in every space and by giving them a uniform taper of 1 in 100, continuity of metal is preserved to meet any stress at that part in a circumferential direction. By this plan end-strength is greatly increased, and all the metal of the gun is made to contribute towards stress in any direction.

Wire guns.

Another method of construction which is now under trial is the application of steel wire for further increasing the tangential strength, and thus reducing the thickness of metal.

* Introduced by Col. Maitland, R.A.

This principle was advocated many years ago by Mr. Longridge, C.E.; but as it was capable of increasing only the ring-strength of a wall, it could not formerly be applied to the service method of manufacturing guns. Now, however, with the arrangement for longitudinal strength just described, it seems as if wire could be advantageously used in lieu of some portion of the external hoops.

Strength.

Steel wire can be made of a tenacity equivalent to 100 tons per square inch; but after reasonable reduction for interstices in winding and possible imperfections in the wire, its strength in comparison with a solid steel hoop must not be estimated higher than 80; even at that measure of tenacity it is the strongest material that has yet been used in the manufacture of guns.*

Objections.

The chief arguments against the use of steel wire are that it possesses absolutely no longitudinal strength; and that it is liable to injury if exposed on the outside of a gun.

Various attempts.

Various plans have been tried for giving end-strength to guns of "wire-construction," such as an external jacket, wrought iron bars in a frame, or wire itself clamped in longitudinal layers; but none of these plans have yet proved quite satisfactory. With a solid breech-piece, however, supplying all the longitudinal strength, this difficulty is now overcome, and exterior hoops may be replaced to a certain extent by coiled wire. Still a jacket or sheath of some sort would be necessary to protect the wire from splinters of shell, and to preserve it from injury in transport: a jacket sufficiently thick for this purpose would constitute a heavy part of the gun without affording much additional strength, but the superior tenacity of wire might outbalance a certain amount of dead-weight.

R.G.F. wire construction.

The chief difficulty in wire construction lies in devising a method of introducing enough relative amount of wire to make a satisfactory reduction of weight. This difficulty has been met in the Royal Gun Factory by a plan which may shortly bring wire into practical use. This consists in employing a barrel of the full length of the gun for the breech-screw again to gear into this tube, but the thickness of metal surrounding the screw is greater than the thickness elsewhere to avoid failure in this part of the gun. The metal is then cut down over the chamber in steps to form a hollow portion extending almost from the screw to the middle of the gun; over this part the wire is coiled. Compression can be brought to bear in this manner with greatest intensity over the seat of the charge, where circumferential strength is most needed. A ring for securing the ends of the wire must be specially prepared and fixed at one end of the coil: this contributes little to strength, but a wire-fastener is of course indispensable, and compensation can be easily made at this point by strength in another piece of the gun.

The mode of fastening adopted is by means of a plug screwed tightly down on the end of the wire, which is bent cold to fit into a recess under the screw. In the same way the other end of the wire is secured after placing a clamp to prevent the tension from getting relaxed, but it is advisable to heat an inch or two at this end with a blow-pipe before bending it round, to avoid the chance of failure by breaking. If broken, the whole length would have to be taken off and a new piece coiled on instead, the first length being too much shortened by snapping. The heads of the screws are not filed off until the whole operation of coiling has been successfully finished.

* Great difficulty was at first experienced in obtaining wire of this quality in the trade; short pieces might generally pass the requisite tests, but when tried over the whole length of the hank, they as generally failed.

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When the hollow part of the A tube has been completely filled up with wire, and all interstices plugged carefully with pieces of packing, a trunnion ring is shrunk on from the muzzle, which is locked and keyed in position; then a jacket is shrunk on from the breech and rigidly connected with the trunnion ring by another locking joint, a good shoulder being provided within at the breech to take the longitudinal thrust. In this way the wire is brought close to its work and able to exercise great initial compression; its full strength is applied in a circumferential direction, while end-strength is provided by the system of locking the portions together, and by the thickness and mass of the jacket.

Advantages in the use of wire.

The advantages claimed for the use of wire may be stated as follows:—

(1) That the circumferential strength in a given thickness of wire is greater than that of any solid metal; and this advantage can be increased in proportion to the amount of wire introduced into the gun.

(2) That the weight of a piece may consequently be much reduced.

(3) That the initial compression given to the barrel will be uniform, and guaranteed in amount; that it is also greater than the compression which shrinkage by heat can effect.

(4) That the tension of the wire may be varied: it can be relaxed at the muzzle, and regulated in successive layers at the breech.

(5) That being mechanically applied, want of skill in the workman will not affect the tension of the wire or quality of the work.

(6) That serious flaws cannot exist as a hidden danger in the wire part of a gun; and that even rupture of a strand would not materially affect the whole strength.

Difficulties in the way of adoption.

Some of these are very powerful arguments in favour of wire, especially the reduction of weight, definite tension, and freedom from flaws; but there are plainly difficulties in the way of adopting a new system of gun manufacture. New machinery would be required, and manufacturing details must be fully worked out by means of experiments on a most liberal scale. The subject is engaging attention, and shortly we may see powerful guns in the service in which wire enters more or less in their construction. On the other hand we appear to have reached a sort of limit in the reduction of weight, for the difficulty of controlling recoil (even with hydraulic machinery) which is becoming almost too complicated for conditions of war has been the cause of a suggestion to *add weight* to the gun or the carriage. If additional weight is allowed, it may as well be placed in the gun to provide a higher factor of safety, and the chief object for adoption of wire is removed.

Conditions in the use of wire.

A few points may be mentioned in regard to the use of steel wire. Each layer should be wound on the gun with a definite and calculated tension. The amount of tension would depend on such circumstances as these, viz.:—the position along the gun, distance from the bore, elastic limit of the wire, and the internal pressure which would have to be resisted. Nor should it be overlooked that the tension of putting on is not the strain under which it would exist when the gun is completed; for the primary tension of the inner layers will be relaxed, and may even be converted into compression, by superimposing the external wire.

In a finished gun there should be one layer of metal in a neutral condition, so that the sum of the tensions exterior to this should be equal to the sum of the compressions within. When fired, the internal

pressure should exercise a definite force, so that all compression should be changed into tension, and all the tensions should be increased. On the point of rupture, every layer should be strained to its full limit of strength. Then the product of the bursting pressure into the radius of the bore would be equal to the thickness of the whole wall of metal into the ultimate tenacity of the material employed.

CHAP. III.

PART I.

CHAPTER III.

ON RIFLING.

Object of rifling.—Rotation of projectiles.—General character of rifling in M.L. and B.L. guns.—Centring of the shot.—Driving side of a groove.—Twist of the rifling.—Uniform twist.—Formula connecting the angle of rifling with twist expressed in calibres.—Actual turn of the groove in a gun.—Advantages and objections to uniform twist.—Increasing twist.—Parabolic curves.—Method of ascertaining the curve, and of calculating the tangent and twist at any point in the groove.—Actual turn of the groove in the gun.—Increasing twist commencing with a small angle of rifling.—Semi-cubical parabola.—Table of formulæ for any description of parabolic curve.—Combination of increasing and uniform twist.—Velocity of rotation.—Revolutions per second.—Twist required for stability in the shot.—Pressure in the grooves.—Forms of groove in service artillery.—Description of the Shunt, Plain, Woolwich, and other grooves in M.L. guns.—Stop for projectiles in the bore.—Description of the Armstrong, M.M. and M.B. systems of rifling.

Rifling rendered necessary by the adoption of elongated projectiles.

GREAT increase of power was given to artillery fire by the adoption of elongated projectiles, instead of the spherical shot and shell formerly used; but then for range and precision of fire it became necessary to devise some means for keeping an elongated projectile point foremost in the air. Such a position can only be maintained in cylindrical bodies by rotation about their longer axis; and the velocity of rotation must be sufficiently great to counteract the forces in gravity and resistance of the atmosphere which tend to establish motion in a contrary direction, and which would soon cause the projectile to turn over and fall to the ground.

Rotation.

This rotation is imparted to the shot by means of the rifling or grooves cut spirally in the bore, which exert a pressure against studs or projections arranged on the body of the shot. The lateral thrust, when properly distributed over the surface of the projectile, compels it to turn round on its axis while onward motion is being imparted to it by pressure of gas in the bore. On leaving the muzzle, therefore, two kinds of velocity will have been impressed on the shot: a velocity of translation through the air, and a velocity of rotation about its longer axis of figure.

Variety of systems of rifling.

Many systems of rifling have been invented and tried, but a few only have been adopted for service. In each case the form of groove must be adapted to the provision made on the shot, or *vice versâ*, for these conditions are complementary one to the other, and must never be infringed; it may also be noticed that a broad distinction exists between the nature of rifling to be found in muzzle and breech-loading ordnance.

In M.L. guns.

In the muzzle-loading guns of our service there are two distinct arrangements applied to the projectiles to compel them to follow the grooves, viz.: (1) by means of large studs on the body, or (2) by

projections on, or the expansion into the grooves of a "gas-check" attached to its base. The projectile must be able to pass freely down the bore of the gun when loading, and there must be clearance or windage in the grooves as well as over the body of the shot. This windage affords an opportunity for the powder gas to rush past the projectile before it has been well set in motion, and in doing so it scores the metal, and destroys the rifling and bore of the gun. With the use of gas-checks this evil is partly avoided; but whether the rifling is intended for gas-checks or studs there are points of similarity in all muzzle-loading systems, such as the existence of a "loading side" in the groove, and some method of centering the shot.

Dimensions and number of grooves.

With studs it is desirable to limit the number of rows, which must unavoidably weaken the shell, but three at least are essential for properly centering the shot. A small number of grooves necessitates depth and width in their dimensions, depth for bearing surface to give the rotation, and width for thickness of stud to prevent its being shorn off. The more numerous the grooves the more shallow may the rifling be made; and this point affects the strength of the gun, for deep grooves in a barrel form lines of least resistance to an internal pressure which might lead to cracks in the metal.

In B.L. guns.

In breech-loading guns we have also two distinct methods applied to the projectiles for obtaining rotation, but only one general character of groove. With the Armstrong or "R.B.L." guns which were made about twenty-five years ago, the shell are supplied with a thick coating of lead, and the first movement of the shot in the bore cuts grooves in the lead corresponding with the lands of the rifling. The difficulty of attachment of the lead coating was great, and it used also to "strip" in the gun instead of following the twist of the groove, which destroyed the rotation and consequently led to bad shooting: the tendency to strip was, however, reduced by lapping out the bore towards the muzzle. The grooves had to be deep on account of the softness of lead; and the twist was necessarily uniform that the projectile might follow the grooves. In B.L. guns of new type a copper band has been substituted for the coating of lead. Bands of different material and shape have been tried, but their duty is in all cases the same; the soft metal is forced into the rifling by the first pressure of gas, and then taking the form of the grooves the driving sides of the latter exert a pressure all round and give rotation to the shot. There is obviously no loading edge, so the other side is sloped off into the bore.

Centering of the projectile.

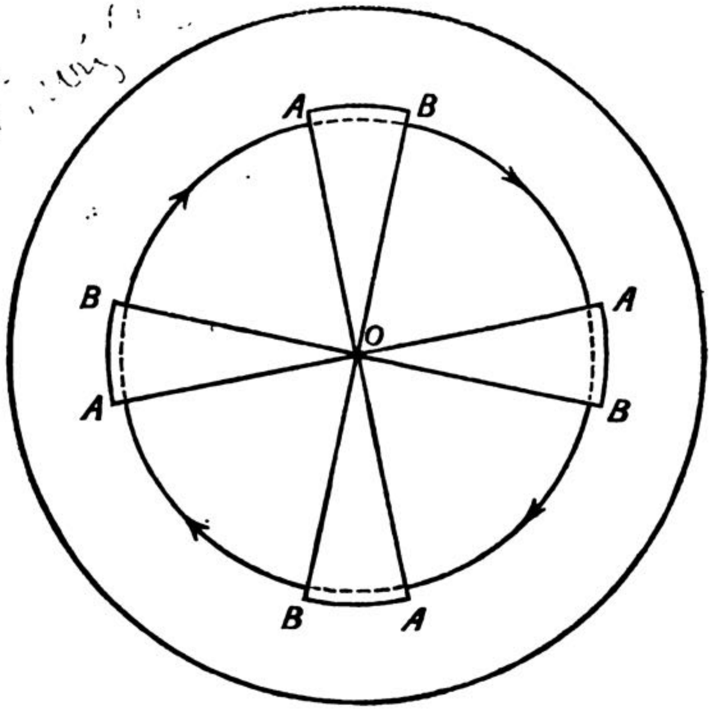
Steadiness of flight will depend to a great extent both on the absence of windage, and on a true centering of the shot in the bore. With B.L. guns there is no difficulty on either of these points, for the soft metal band and the form of the groove tend to bring the shot to a concentric position in the bore, while all windage is theoretically closed; but with M.L. pieces, a variety of plans have been tried to make the axis of the shot coincide with the axis of bore: these methods can best be explained in connection with the grooves which will be described at the end of this chapter.

Driving side of a groove.

It is necessary to understand clearly which is the "driving" side in a groove. With a right-handed twist (and the twist is always right-handed in British artillery) the left side at the top of the bore and the right side at the bottom, when standing behind the gun, will be the side in contact with a stud when the shot is fired out of the gun: or standing at the muzzle, where the rifling can best be inspected, the positions are reversed, and on the lower surface of the bore the left is the driving side of the groove.

Perhaps this point can be better explained by considering the two

CHAP. III. radii OA and OB in the figure, which form the two sides of a groove: then looking *towards* the muzzle from the breech of the gun the radius



OA in any position will represent the driving side of the groove. Changing the point of aspect from the breech to the muzzle, the driving side will be shown by OB.

Twist. Deferring for the present any description of the shape of a groove, we will proceed to investigate first the *twist* that should be given to the rifling.

Uniform or increasing. Twist may either be uniform in character throughout the whole length of the groove, or it may vary by an increase of pitch: both uniform and increasing twist may also be combined.* Uniform twist is the most simple kind, and therefore best suited for investigation in the first instance.

Uniform Twist.

Expression for twist. Twist may be expressed in two ways: either by the angle or pitch of the rifling, or by the rectilinear distance in which the spiral would make one complete turn; the latter is the more usual method, and the unit of measurement then commonly taken is the calibre itself of the gun.

Formula. These two expressions for twist may be connected by a very simple formula, so that if either is given the other may be soon ascertained. This can be shown by the aid of a figure, as given next page.

Let a straight line AB be equivalent to n calibres in length, that is, the distance (measured parallel to the axis of the piece) in which the spiral would make one complete turn.

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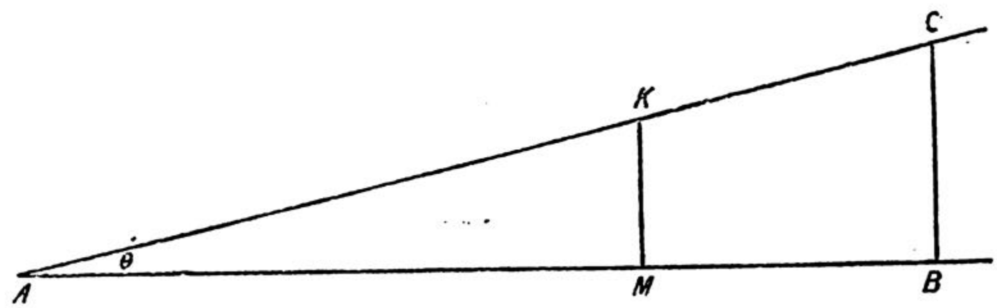
* A decreasing twist has been suggested, but the suggestion does not appear to have been fully thought out.



Draw BC perpendicular to AB, of a length equal to the perimeter of the bore; join AC. Then CAB is the angle of rifling, say θ, and

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$$\tan\theta = \frac{BC}{AB} = \frac{2\pi r}{nd} = \frac{\pi}{n}$$

Example. For example, take the 64-pr. R.M.L. gun, the rifling of which has a uniform twist of 1 turn in 40 calibres:—

$$\theta = \tan^{-1}\frac{\pi}{40} = 4^\circ\ 30'.*$$

Actual turn. The actual amount of turn which a groove makes within the bore of a gun may now be easily calculated, for if AM or l inches be taken to represent the length of the rifled part of the bore, MK will be the actual amount of turn at the muzzle: and

$$MK : AM :: BC : AB$$

therefore $$MK = l\tan\theta.$$

To ascertain the proportion which MK bears to a whole turn or circle of the bore, the length AB must be converted into inches, say l'; then the ratio may be written—

$$\frac{MK}{BC} = \frac{AM}{AB} = \frac{l}{l'}$$

$$\text{or } MK = \left(\frac{l}{l'}\right) \text{ of the bore.}$$

Advantages, &c., in uniform twist. Uniform twist possesses the advantage of simplicity; the bearing parts on the projectile may also be distributed over the whole body of the shot, and the projectile leaves the muzzle with steadiness of flight. On the other hand, the sharp pitch of the rifling impedes the first movement of the shot, so that the powder gas may attain very high density and put a severe strain on the gun. To avoid this disadvantage and risk, the fixed angle of rifling has now been exchanged for a groove with an increasing twist, which attains the requisite pitch more or less gradually.

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* As an illustration of a groove in a gun, one may take a large sheet of paper and draw a straight line from one corner at an angle θ with the longer side; then bending the sheet into cylindrical form, the line so drawn will be seen within to represent a helix or groove. This also shows how the spiral becomes a straight line when laid out upon a plane surface.

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Increasing Twist.

Increasing twist.

With an increasing twist there is an imperceptible change from little or no twist at all at the commencement of rifling up to a maximum pitch at the muzzle, or at some other point in the bore if the projectiles are adapted to this form of rifling. It will be convenient at first to consider the maximum twist at the muzzle.

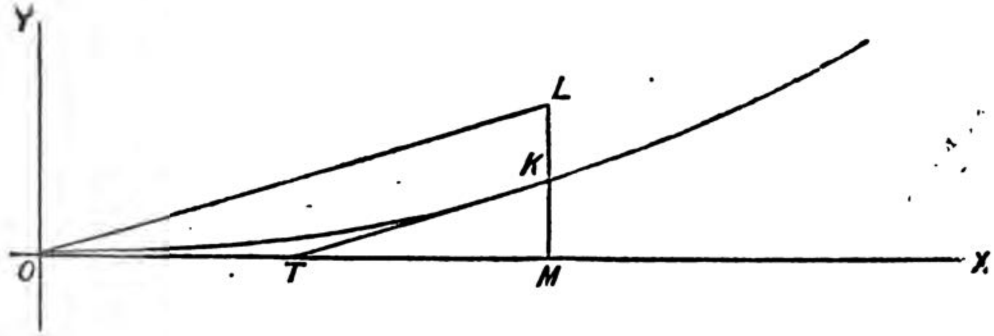
Comparison of uniform and increasing twist.

When the grooves start almost parallel to the axis of the bore there is very little hindrance to the first motion of a shot, at a time when its own inertia and friction in the bore might be the cause of setting up heavy pressure of gas; but there is greater friction afterwards in the grooves because the driving sides continue to exert pressure on the studs as long as the pitch of the rifling increases. With uniform twist there is a tendency to shear the soft metal and for the studs to "over-ride" in the grooves, from the fact of this pressure being suddenly exerted at first with very great force, but afterwards the shot travels more freely because friction then only depends upon increments to the onward velocity. The gun is put to a great strain at the breech in one case, while in the other the stress is diffused and much heat is developed by friction with increasing twist; it should also be said that the projectile is relieved of a very heavy pressure on its base which tends to crush up the shell. The velocity of rotation is not affected by this question of twist, because that will depend with a given muzzle velocity in the shot on the final twist at the muzzle. Uniform twist is more favourable to steadiness of flight, but this can be secured with the advantages of increasing twist by a combination of the two, a plan which is generally adopted in all modern pieces of ordnance.

Curve for increasing twist.

For increasing twist, the development of a groove on a plane surface would result in a curve, instead of a straight line as shown to be the case for uniform twist. The curve chosen in our service (with the exception of the 80-ton guns) is the conic parabola $x^2=py$, because this curve has the property (so to speak) of increasing uniformly; that is to say, the increase of pitch, or rather the increase in the value of the tangent $\frac{dy}{dx}$ between any consecutive points is a constant.

When first applied to a system of rifling, the vertex of the curve was taken for the commencement of the groove, then the twist at the muzzle being fixed, and the length of the rifled part of the bore being known, the data were sufficient to draw out the curve.



The points to be determined from the foregoing conditions are these:—

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(a) The constant in the equation $x^2 = py$;
(b) The ordinate at any point;
(c) The tangent to the curve or angle of rifling; and
(d) The twist in calibres.

First to find the value of p.

The constant.

By differentiating the general equation $x^2 = py$ we may obtain an expression for the tangent at any point on the curve: thus—

$$2\,x\,.\,dx = p\,dy.$$

$$\frac{dy}{dx} = \frac{2\,x}{p} = \frac{2\,x^2}{px} = \frac{2\,py}{px} = \frac{2\,y}{x}$$

At the muzzle we have from the data

$$\frac{dy}{dx} = \tan\alpha = \frac{\pi}{n}; \text{ and } x = l.$$

Therefore $$y = \frac{\pi l}{2n}.$$

Then substituting these values of x and y in the general equation

$$y = \frac{x^2}{y} = \frac{2\,nl}{\pi}. \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (a)$$

The ordinate.

Secondly, to find the value of y, or ordinate at any point; this is practically required in making the copying bar for a rifling machine:

$$y = \frac{x^2}{p} = \frac{\pi\,b^2}{2\,nl}. \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (b)$$

The tangent.

where b is the abscissa or distance from the beginning of the rifling of any given point in the bore, measured parallel to the axis of the piece.

Thirdly, to find the angle of rifling:—

$$\tan\theta = \frac{dy}{dx} = \frac{2\,y}{x} = \frac{\pi b}{nl} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (c)$$

The twist in calibres.

and lastly, to express the twist in calibres:—

$$\tan\theta = \frac{\pi}{N}.$$

Therefore $$N = \frac{\pi}{\tan\theta} = \frac{nl}{b}. \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (d)$$

A defect is very commonly spoken of as lying (say) "half-way" down the bore. The unit of length is thus changed from an inch to the whole length of the rifled part of the gun, and the point previously denoted by the abscissa b is now indicated by some fractional part of that length. Let us call this fraction $\left(\frac{1}{z}\right)^{\text{dth}}$. It will now be seen by the formula given for twist in calibres, that $N = \dfrac{n}{\frac{1}{z}}$ at a point described in this manner; hence $N = zn$.

Twist at any point in the bore.

This simple expression supplies a ready method of ascertaining the twist at any fractional distance throughout the whole length of the bore; thus when—

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$$b = \tfrac{1}{10}\text{th of } N = 10\,n.$$
$$b = \tfrac{2}{10}\text{ths }„\ N = 5\,n.$$
$$b = \tfrac{5}{10}\text{ths }„\ N = 2\,n, \&c.$$

Turn of the groove.

With increasing twist of this kind the actual turn of the groove in the gun is just half the amount due to a uniform twist having the same angle of twist at the muzzle. This can be shown in the following way:—

Take the portion OK on the curve in the foregoing figure to represent a groove in the gun, and let OM be the length of the rifled part of the bore. Draw the tangent KT and a line OL through the origin parallel to KT. OL will represent a groove for the same gun with uniform twist, and the angle of rifling at the muzzle is evidently the same in each case.

By the property of a parabola OT = TM, and therefore MK = KL; so the actual turn of the groove with increasing twist is just half as much as it would have been with a uniform twist having the same pitch at the muzzle.

This may be proved also from the general equations to the curve and the straight line. For we have seen that

$$\tan \alpha \text{ or } \frac{\pi}{n} = \frac{dy}{dx} = \frac{2l}{p} \text{ at the muzzle,}$$

so the equation to the straight line OL, which is parallel to KT, may be written

$$\frac{y_1}{x_1} = \frac{2l}{p}$$

Now comparing the values of y and y_1 at the muzzle when x and x_1 were both equal to l,

$$y = \frac{l^2}{p} \text{ and } y_1 = \frac{2l^2}{p}$$
$$\text{or } y_1 = 2y$$

Groove commencing with a twist.

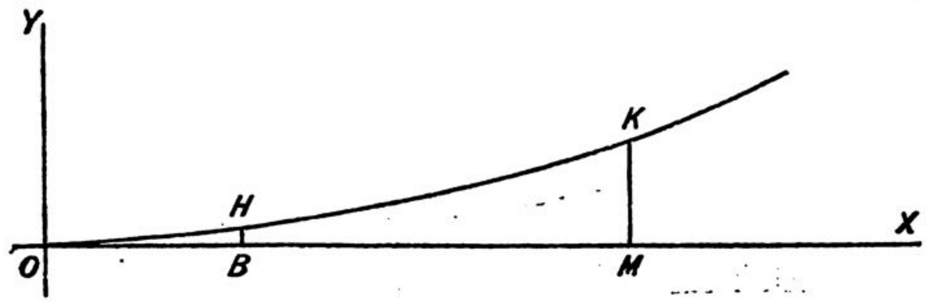
It is not necessary, however, that the commencement of the groove should correspond with the vertex of the curve; in most heavy guns a small part of the curve is discarded, and another portion is taken, so that a slight twist may be given to the rifling from the very beginning. The twist at the muzzle can be regulated to have any particular value by changing the constant in the equation; the development of twist thus becomes still more gradual, and the rifling better suited to projectiles of very great weight.

The investigation in this case may be made as before after first ascertaining the length of the abscissa which is required to complete the curve to the vertex. The value of this may be found in the following manner:—

Let l be the length of the rifled part of the bore, and let the twist increase from 1 turn in m calibres at the breech to 1 turn in n at the muzzle.

Take HK in the figure here given as the portion representing the groove, and let $(x_1\ y_1)$, $(x_2\ y_2)$ be respectively the co-ordinates of H and K. Then.

$$\text{OB} = x_1,\ \text{BM} = l \text{ and OM or } x_2 = x_1 + l$$



At the muzzle $\tan \alpha = \frac{\pi}{n} = 2 \frac{y_2}{x_2}$

and at the breech $\tan \beta = \frac{\pi}{m} = 2 \frac{y_1}{x_1}$.

Hence $$y_1 = \frac{\pi x_1}{2m}$$

and $$y_2 = \frac{\pi (x + l)}{2n}.$$

Now the ordinates to a conic parabola vary with the second power of the abscissæ; consequently

$$y_1 : y_2 : : x_1^2 : (x_1 + l)^2$$

and we have shown that

$$y_1 : y_2 : : \frac{x_1}{m} : \frac{x_1 + l}{n}$$

therefore $$m x_1 = n (x_2 + l)$$

or $$x_1 = \frac{nl}{m - n}$$

and this is the quantity, which we will call a, that is required to complete the curve to the vertex. The value of p and the ordinate and twist at any point can then be determined in the manner already explained.

Semi-cubical parabola.

There is one exception in the service to the use of the conic parabola for an increasing twist, and that is in the 80-ton R.M.L. gun: for this a semi-cubical parabola has been adopted which is represented by the equation $x^{\frac{3}{2}} = py$, because this form of curve has the property of developing the twist still more gradually. It is specially suitable for a heavy projectile which is fitted with a rotating gas-check: compared with uniform twist the pressure in the grooves is still further relieved at the breech, and compared with the ordinary increasing twist the risk of shearing at the muzzle is reduced when the gas-check is insufficiently supported by the pressure of gas on the base of shot.

Most general equation.

Taking the most general form of equation, $x^q = py$, a table may be compiled which will give the value of a, y, $\tan \theta$, and N for all possible conditions of rifling with these parabolic curves. (See next page.)

TABLE IV.

TABLE of Formulæ for the co-ordinates and twist at any point in a parabolic curve representing a rifle groove, in terms of the twist of the rifling.

	Conic Parabola $x^2 = py$.		Semi-cubical Parabola. $x^{\frac{3}{2}} = py$.		General Parabola. $x^q = py$.	
	From the vertex.	On the curve.	From the vertex.	On the curve.	From the vertex.	On the curve.
Abscissa for the commencement of the curve ..	—	$\frac{n}{N-n}$ *	—	$\frac{n^2 l}{N^2 - n^2}$	—	$\frac{n^{\frac{1}{q-1}} l}{\frac{1}{N^{\frac{1}{q-1}}} - \frac{1}{n^{\frac{1}{q-1}}}}$
Ordinate to any point, $x = b$	$\frac{\pi b^2}{2 n l}$	$\frac{\pi (a+b)^2}{2 n (a+l)}$	$\frac{2}{3} \frac{\pi b^{\frac{3}{2}}}{n (l)^{\frac{1}{2}}}$	$\frac{2\pi}{3n} \frac{(a+b)^{\frac{3}{2}}}{(a+l)^{\frac{1}{2}}}$	$\frac{\pi b}{q n^{q-1}}$	$\frac{\pi (a+b)^q}{q n (a+l)^{q-1}}$
Value of $\tan \theta$	$\frac{\pi b}{n l}$	$\frac{\pi}{n} \frac{a+b}{a+l}$	$\frac{\pi}{n} \left(\frac{b}{l}\right)^{\frac{1}{2}}$	$\frac{\pi}{n} \left(\frac{a+b}{a+l}\right)^{\frac{1}{2}}$	$\frac{\pi}{n} \left(\frac{b}{l}\right)^{q-1}$	$\frac{\pi}{n} \left(\frac{a+b}{a+l}\right)^{q-1}$
Twist in calibres	$n \frac{l}{b}$	$n \frac{a+l}{a+b}$	$n \left(\frac{l}{b}\right)^{\frac{1}{2}}$	$n \left(\frac{a+l}{a+b}\right)^{\frac{1}{2}}$	$n \left(\frac{l}{b}\right)^{q-1}$	$n \left(\frac{a+l}{a+b}\right)^{q-1}$

* The value of the abscissa in a conic parabola may also be found for a particular gun by means of the expression given on page 51, when the degree of twist at each end of the groove is given. It was shown that OB, or a, might be described as $\left(\frac{1}{z}\right)^{\text{th}}$ of OM, that is, $a = \frac{a+l}{z}$. It was also shown with regard to the twist at any point on the curve $\left(\frac{1}{z}\right)^{\text{dt}}$ from the vertex that $N = z\,n$; eliminate z between these two equations, and we find that $a = \frac{nl}{N-n}$.

CHAP. III.

Combination of Increasing and Uniform Twist.

Combination of increasing and uniform twist.

In modern guns, both M.L. and B.L., the advantages derivable from each nature of twist are secured by a combination of the two; this combination, however, can best be applied to very long guns, so B.L. guns of new type are capable of exhibiting this kind of rifling with the greatest success. The twist may commence at the breech from zero or with a definite pitch (the latter is now always preferred) and at some point in the bore, when the inertia of the projectile has been overcome and the increments of velocity are small, the curve is exchanged for a straight line representing uniform twist. With muzzle-loading guns this portion of uniform twist was necessarily short, and the combination will not be found where the rifling was made for studded projectiles; but with rotating gas-checks it is found necessary to relieve the shell of lateral pressure as soon as the powder gas ceases to give sufficient support for attachment. In B.L. guns of new type, where length of bore and the rotating band both favour this combination of twist, the change is made about midway in the rifling; it is then found to promote high muzzle velocity with steadiness in flight, and good shooting results from the stability of projectiles in the air.

Velocity of Rotation.

Velocity of rotation.

The spin of a projectile will depend upon its muzzle velocity and the final twist of the rifling. With these two data we can soon ascertain the speed of rotation, or the number of revolutions per second.

Let V be the velocity of the shot and n the twist at the muzzle. Then in a given time (t) the rectilinear and angular velocities will evidently describe distances equal to Vt and ωt respectively. By the twist of the rifling it follows that when $Vt = nd$, $\omega t = 2\pi$. Eliminate t between these equations and $\omega = \frac{2\pi}{nd}V$, where ω is the angular velocity.

Revolutions per second.

Now to obtain revolutions per second, we must divide this expression for angular velocity by the measurement of one revolution, that is, by 2π, and we find that the number of revolutions per second is $\frac{V}{nd}$.

To avoid the use of angular velocity (if that term should suggest any difficulty) linear measurement of the rotatory motion may be taken by supposing the shot to be spinning without translation through the air. Then in the time occupied by this point in making one revolution πd, the shot (if it had onward velocity) would have moved through a rectilinear distance nd. Hence if the linear amount of rotation be represented by a symbol λ, $\frac{\lambda}{V} = \frac{\pi d}{nd}$, or $\lambda = \frac{\pi}{n}V$. To reduce this expression to revolutions per second as before, we must divide by the *perimeter* of the circle this time, πd, and then we obtain the same formula as that given already, viz.:—

$$\text{Revolutions per second} = \frac{V}{nd}.$$

CHAP. III.

Twist required for Stability.

The question will naturally arise, what ought to be the velocity of rotation, or actual twist of the rifling?

Twist necessary for stability.

This subject has been discussed by Professor Greenhill in an article which was published in the Proceedings of the Royal Artillery Institution in 1879. His investigation is rather abstruse, but stated briefly it may be summed up as follows:—

Supposing the projectile to be of the form of a prolate spheroid, moving in frictionless air and under no forces. At the muzzle $\tan \alpha = \frac{\pi}{n} = \frac{r\omega}{V}$, and therefore $n \frac{2\pi V}{\omega d}$. Now taking into the consideration the specific gravity of the shot, and the ratio of its weight to that of the air which is displaced; also the axis of figure and radius of gyration, &c., Professor Greenhill eliminates velocity altogether from this expression for n, and arrives at the conclusion that n must be equal to $\left\{ \frac{\pi^2 k_3^4}{4\, a^2 k_1^2 \frac{\rho}{\sigma}(\alpha-\gamma)} \right\}^{\frac{1}{2}}$* where k_1 and k_3 are the equatorial and polar radii of gyration; a is the semi-diameter at the centre of gravity; $\frac{\rho}{\sigma}$ the ratio of weights in the projectile and volume of air displaced; and α and γ are constants depending on the shape of the body.

Value of n.

This shows that n should have the same value for similar projectiles, if made of the same material, whatever the calibre of the gun.

In the application of this to hollow shell, whether empty or filled, the internal dimensions must of course be approximately known, and also the specific gravity of the contents of the shell. Assuming that the cavity is similar in form to the external figure and of two-thirds the linear dimensions, it is found when the length of the projectile is three times the diameter that

$$n = 38{\cdot}449 \text{ for empty shell,}$$

and

$$n = 39{\cdot}06 \text{ for shell filled.}$$

Here the difference is small, but with filled shell the stability is slightly increased.

A much greater difference will be found if more elongated projectiles are used without change of calibre, such as double shell which may be considered to be four diameters in length. The value of n by the same method of calculation then becomes 27·6 and 28.

It would thus appear that twist cannot strictly speaking be suitable for different projectiles which vary materially in character or size. The rotation which is sufficient for a short Palliser shot would be too little

* There is a slight obscurity in this expression for n, because the value would appear to depend on the diameter of the shot. Professor Greenhill, however, has explained that if we suppose the projectile to remain of the same general shape, but compare projectiles of different sizes, then $\frac{\rho}{\sigma}$ $(\alpha-\gamma)$, remains the same, but the calibre $d = 2a$ may vary. Nevertheless, $\frac{k^4_3}{4a^2k^2_1}$ will remain constant, for k_3^4 varies as a^4, and k_1^2 as a^2; so that $\frac{k_3^4}{a^2 k_1^2}$ will remain constant although a (and consequently k_1 and k_3) may vary.

for a long double shell, and without stability or steadiness in flight the drift is uncertain and the shooting very irregular. On the other hand, excessive rotation throws additional work on the gun, with a risk also of shearing the studs or projections supplied to the shot.

The twist at the muzzle expressed in calibres will be found, as a rule, in the guns of our service, to lie between 40 and 25; 30 is now generally adopted for projectiles of modern proportions; the exact value, however, has been mainly determined by practice, for if the firing trials of any new nature of gun show that the shell are unsteady in flight, the twist is increased until the shooting becomes satisfactory.

Pressure in the Grooves.

Pressure in the grooves.

The pressure exerted by the driving side of the groove on the studs or projections of a rotating band, is evidently some function of the onward velocity in the bore. With uniform twist a thrust is given by the grooves to the studs on first contact which imparts a rotation to the shot, and any increment to the velocity of rotation must be due to an increase in the onward velocity; so the pressure in the grooves bears a constant relation to the pressure on the base of the shot. With an increasing twist, the pressure will continue to increase with the twist, as well as with the increments of velocity in the bore.

Maitland's table.

A table was compiled by Colonel Maitland, R.A., some years ago to show the pressures in the grooves of a 12·5-inch R.M.L. gun under different systems of rifling. It will be seen from this table, which is given on page 60, that with uniform twist the pressure is irregular and very heavy indeed just after the shot has begun to move in the bore. To relieve this strain at the commencement an increasing twist was adopted, the curve chosen being a conic parabola. Much greater regularity in this case was observed; the maximum stress was reduced; and the table of pressures was changed from a decreasing to an increasing series, which showed that the pressure in the grooves then increased proportionately with the increase of twist. The sudden falling off of pressure at the muzzle is due to a change in the rifling, which there proceeds uniformly for reasons already explained.

An inspection of the last column will show the reason for adopting a semi-cubical parabola for the rifling of the 80-ton gun. The first part of the curve from the vertex is there set aside, and the portion selected begins with a twist of 1 turn in 200 cals. The maximum pressure is here further reduced, and there is some approach to uniformity of strain. In all three cases the twist at the muzzle is the same. The figures were derived from several formulæ worked out by Captain Noble, of Elswick; but Lieutenant Younghusband, R.N., has supplied a general formula which is applicable to any curves of parabolic equation,* viz.:—

Where

$$R = \frac{\rho^2 \left(G \tan\theta + \frac{d^2 y}{dx^2} M v^2\right) \sec.\theta}{r^2 (1 + \tan^2\theta) - \mu \tan\theta (r^2 - \rho^2)} \sqrt{1 + \mu^2}$$

* This formula and Col. Maitland's table of pressures were published in the 9th edition of *Encyclopædia Britannica*, under the head of "Gun-making."

CHAP. III.

Where

R = the rotation pressure between groove and stud.
G = gas pressure on the base of the shot.
M = mass of the shot, or $\frac{W}{g}$.
μ = co-efficient of friction.
θ = angle of rifling at any point.
r = semi-diameter of the shot.
ρ = radius of gyration.
v = velocity of the shot.

TABLE V.

TABLE showing **Pressures of Grooves on Studs in a 38-ton R.M.L. Gun with various Curves of Rifling.**

Charge, 130 lb. cubical powder of 1·25-inch edge.
Projectile, 800 lb. Calibre, 12·5 inches.

Travel of shot through bore.	Time of travel.	Velocity acquired.	Pressure on base of shot.	Pressure per square inch of base.	Pressure on studs with uniform twist of 1 turn in 35 cals.	Pressure on studs, parabola twist, 0 to 1 in 35 cals.	Pressure on studs, semi-cubical parabola, 1 in 200 cals. to 1 in 35 cals.
ft.	secs.	f.s.	tons.	tons.	tons.	tons.	tons.
·0	·00000	0	2000*	16·3	79·3	·0	31·4
·1	·00143	140	2221·3	18·1	88·1	1·65	22·6
·5	·00273	474	3320·3	27·0	136·6	15·6	59·8
1·0	·00360	676	2060·6	16·8	81·7	26·8	61·3
2·0	·00490	869	1394·1	11·4	55·3	42·1	65·1
3·0	·00598	987	1095·0	8·9	43·4	53·1	66·3
4·0	·00695	1074	908·8	7·4	36·0	61·95	66·3
5·0	·00785	1142	746·4	6·1	29·6	68·7	85·0
6·0	·00871	1195	668·3	5·4	26·5	75·0	64·7
7·0	·00953	1242	592·8	4·8	23·5	80·3	63·9
8·0	·01032	1277	499·4	4·1	19·8	83·3	61·0
9·0	·01109	1309	421·9	3·5	16·7	86·2	58·95
10·0	·01184	1335	355·6	2·9	14·1	88·2	56·6
11·0	·01258	1355	265·1	2·2	10·5	88·1	53·95
12·0	·01331	1369	188·7	1·5	7·5	87·3	48·8
13·0	·01404	1379	131·6	1·1	5·2	{86·4 5·2}	{45·2 5·2}
14·0	·01476	1385	120·9	1·0	4·8	4·8	4·8

* Estimated.

Forms of Groove.

Forms of groove. It remains now to describe the various forms of groove which may be met with in service artillery.*

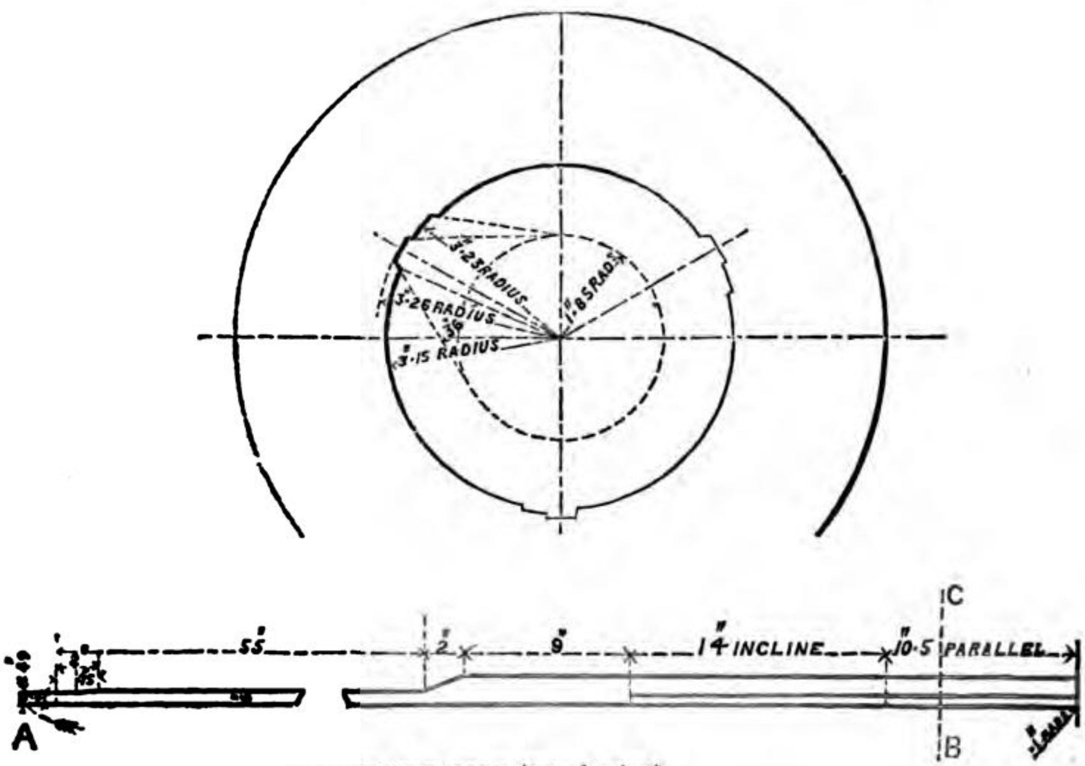
M.L. guns. In muzzle-loading ordnance there are six distinct forms, viz.:—

(1) The Shunt; Obsolete
(2) „ Plain; Changed from shunt.
(3) „ Woolwich;
(4) „ French;
(5) „ French Modified; and
(6) „ M.M., or Maitland-muzzle-loading groove.

B.L. guns. In breech-loading guns there are three, viz.:—

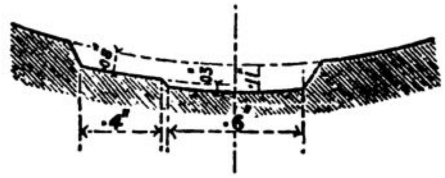
(1) The Armstrong;
(2) „ E.O.C. Polygroove; and
(3) „ M.B., or Maitland-breech-loading groove.

Shunt groove. The "*Shunt*" groove was adopted on the first introduction of R.M.L. guns: it is a groove which varies both in depth and in width, the deeper portion being on the loading side to enable the stud to pass easily down the groove when the projectile is being rammed home from the muzzle.



THE SHUNT GROOVE (muzzle view).

* Many other forms have been invented and tried—far too many to be enumerated here; the most interesting, however, may be seen in experimental pieces of ordnance, which have been tried but are now set aside.

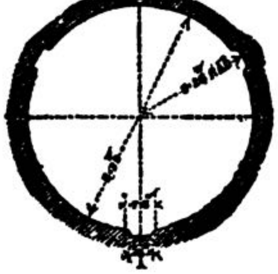


SECTION ON ..... B.C.
FULL SIZE

At a distance of about 3 feet down the bore, the groove contracts to half the width it possessed at the muzzle, and the inclined edge of the loading side there shunts the stud over to the driving side of the groove. At the extremity there is a second contraction in one of the grooves which brings all the studs into actual contact with the driving sides, and removes the risk of their being shorn off by impinging against the sharp edge. As the shot is driven out towards the muzzle, the stud follows the driving edge and meets with another kind of contraction in the shape of an inclined plane, which leads up to a more shallow part of the groove; by this arrangement the projectile is slightly gripped on three sides at once and centred in the bore before leaving the muzzle. The shunt system, however, was soon given up, being too complicated, and liable to cause damage to the gun and loss of velocity in the shot. It will be found only in 64-pr. guns, and in them it is being gradually changed for a simple plain groove whenever the opportunity offers.

Plain groove.

The *Plain* groove is practically the deep portion of the shunt, being intended for the same ammunition; the bottom of the groove is

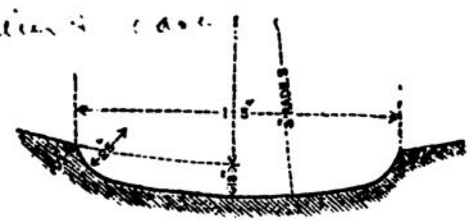


THE PLAIN GROOVE.

concentric with the bore, and the sides are formed by straight lines at the same outward inclination from the bottom of the groove.

Woolwich groove.

The "*Woolwich*" groove differs chiefly from the plain in being rounded off on both sides to avoid sharp angles and prevent any tendency in steel to split along the edge of the groove; the bottom



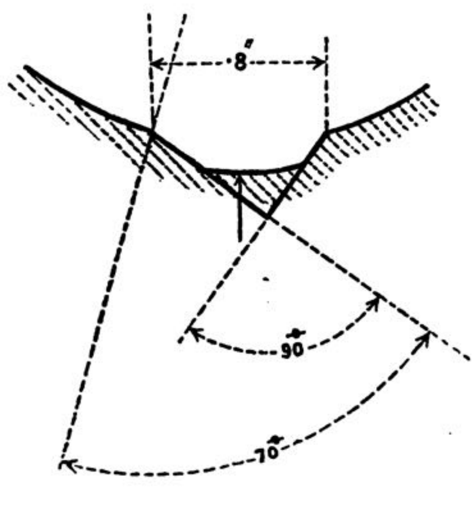
THE WOOLWICH GROOVE.

CHAP. III.

also is struck with a short radius to make it *eccentric* with the bore, an alteration which is intended to facilitate loading and to centre the projectile when fired. This kind of groove will be found in all the heavier natures of R.M.L. guns, but the dimensions will differ, increasing with the size of the gun, as will be seen in the Table which is given on page 212.

French groove.

The "*French*" groove is very similar to the Plain, but the driving edge has a more gradual inclination than the opposite side, with the object of enabling the stud to ride up this incline and adjust itself to a centering position. The sectional form of this groove will be explained by the figure below; the driving side forms an angle of 70° with a normal to the surface of the bore, and the loading side is at right angles to the line thus obtained. The bottom of the groove is concentric with the bore. This will be found only in 7-pr. guns.



THE FRENCH GROOVE (muzzle view).

French modified groove.

The "French Modified" groove is the same as the French as regards the inclination of the sides, but the bottom of the groove is eccentric, and the sharp angles are rounded away to prevent the barrel from splitting along the edge of the groove. This form of rifling was applied to the 9 and 16-pr. guns. only

M.M. groove.

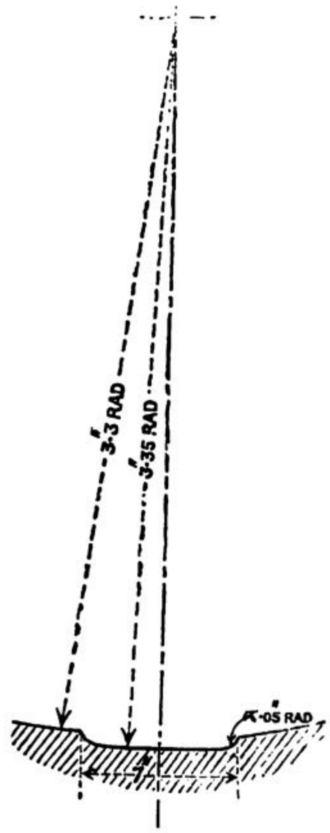
The M.M. or Maitland-muzzle-loading rifling consists of a large number of very shallow grooves; the bottom of each groove is concentric with the bore, and the sides terminate in quadrants of a circle. This curve was selected with the object of exerting the greatest driving power on the projectile with the least disposition to shear the soft metal. It was adopted for rotating gas-checks, and applied first of all to the howitzers. The width varies from ·5 to ·7 of an inch; in the 13-pr. gun the lands have the same breadth as the grooves, but this equality is not always preserved. (See figure on the next page.)

Stop for the Projectile.

Stop.

To regulate the density of the charge and to make sure of ramming the projectile home to the same spot on every occasion, especially when the chamber has a larger diameter than the bore, it is necessary to

CHAP. III.



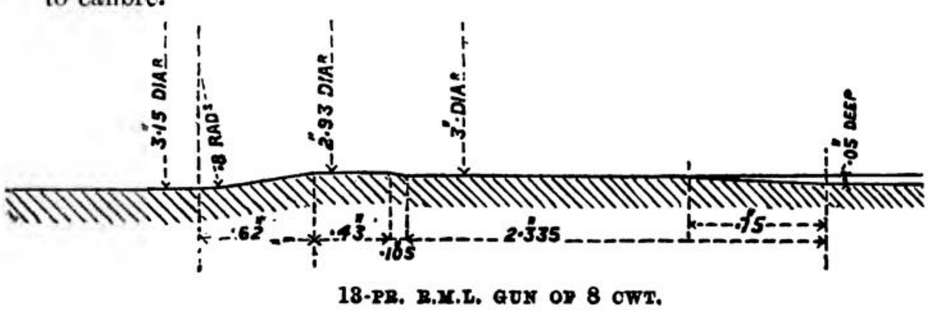
THE M.M. GROOVE.

provide some means of stopping the shot in its proper position in the gun. Two or three modes are employed:—

(1) By making use of the termination of the grooves, in conjunction with the projections on a gas-check, as in howitzers, and the 80 and 100-ton guns.

6·3-INCH R.M.L. HOWITZER, 18 CWT.

(2) By leaving a "choke" or contraction in the bore just in front of the chamber. This plan is suitable for projectiles which have gas-checks without any projections; it was adopted for the 13-pr. R.M.L. gun, but it cannot be applied to ordnance already made and bored out to calibre.



13-PR. R.M.L. GUN OF 8 CWT.

(3) By stiffening the cartridge so that it should always retain its full length, even under the pressure of ramming, and in a chamber of larger diameter than itself. For the 12·5-inch R.M.L. gun, Mark II, which has neither a choke nor a stop in the rifling, sticks were formerly placed in the centre of each portion of the charge; but the adoption of prismatic powder has rendered the use of these sticks unnecessary, for the cartridges are sufficiently stiff in themselves.

Grooves for B.L. Ordnance.

B.L. guns.

For breech-loading guns there are only three kinds of rifling, and all the systems may be called "polygroove."

Armstrong groove.

The "*Armstrong*" groove was adopted in 1859 for B.L. guns of that date; it was suitable for lead-coated projectiles, the lands being narrow and the grooves very deep. A shot chamber of suitable diameter

THE ARMSTRONG GROOVE (muzzle view).

forms a stop in the bore, and determines the position of the projectile in loading; no ordinary force would suffice to drive it beyond this position.

E.O.C. Poly-groove.

The rifling known as the E.O.C. Polygroove is a simple system of shallow concentric grooves, the lands and grooves having generally about the same breadth, with the "driving" and "loading" edges of the grooves arcs of circles of different radii, the "driving" being inclined more abruptly to the normal. It is somewhat similar to the M.B. groove, but the lands are more marked and broader. It is suited to a cannelured soft-metal band which is attached round the base of the projectile, and the termination of the rifling (or commencement of the lands) forms a stop for the front edge of the band. This rifling will be found in the 6-inch B.L. guns 80-pr. and Mark V, and the 8-inch Mark VII, which were all manufactured at Elswick.

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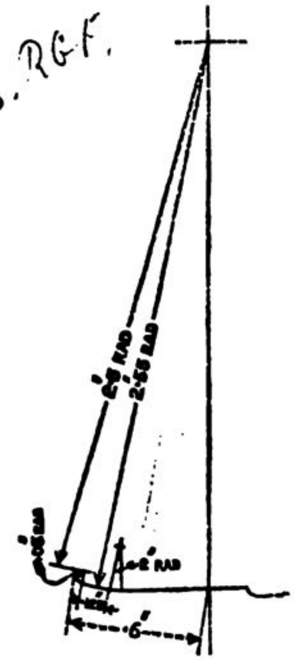
all new type BL guns. RGF.



THE M.B. GROOVE.

M.B. groove.

The most modern system of rifling is known as the M.B. or Maitland-breech-loading groove. This is a very shallow groove to suit a strong copper band, and consists of a driving side only, the curve of which is a perfect quadrant of a circle, as in the Maitland-muzzle-loading groove; the other side is sloped off into the bore, a small portion of which is left to form a land between each two consecutive grooves. The depth varies from ·04 of an inch in field guns to ·06 in the heaviest pieces.

By this system of rifling the barrel is not weakened to an appreciable extent, as in the case of any kind of deep groove, and the number of small driving edges distributes the strain in the gun all round the bore. The commencement of the rifling forms a stop for the projectile in loading, and the front edge of the band is faced off that the shot may be jammed in position, a precaution which may sometimes be needed when the gun is being loaded at much elevation, to prevent the shot from slipping back into the chamber. The twist of rifling in the B.L. guns is increasing to only about half the length of the bore, the remainder is uniform. The narrow driving band adjusts itself to the variation in twist. The number of grooves in a gun with this rifling, as a rule, is four to each inch of calibre. This rifling will be found in all B.L. guns of new type which have been designed in the Royal Gun Factory since the year 1880.

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CHAPTER IV.

POWER OF GUNS.

Work stored up in a projectile, and work done by the gun.—Power measured by the effect of the shot.—Power independent of construction.—Objects for artillery fire.—Velocity of a shot.—Boulengè Chronograph.—The instrument.—The electric circuits.—Adjustments before use.—Disjunctor reading.—Change in distance or height.—Flat-headed projectiles.—Muzzle velocity.—Cubic law of resistance in atmosphere.—Laws of motion.—Bashforth's experiments.—Integrals for space and time.—Formulæ.—Old and new tables.—Examples.—Bashforth's tables.—High angle fire.—Angle of descent.—Pressure in the gun.—The crusher gauge.—Table of compressions.—Pressed coppers.—Correction for deviation from standard quality.—Crushers in the cartridge, base of shot, and axial gauges for B.L. guns.—Small pistons for heavy pressures.—Penetration of wrought iron plate.—Work stored up in a shot.—Guns v. armour.—Noble's formula.—Maitland's formula.—Recent experiments.—Noble's formula modified.—Maitland's new formula and diagram.—Values of $\frac{w}{d^3}$.—Mode of using the diagram.—Col. Inglis's theory.—Captain Orde Browne's rule.—Comparison of power in guns per ton weight of metal.—Table for comparison of British and Foreign heavy guns.—Theoretical calculation of muzzle velocity.—Tables for Factors of effect.—Table of Factors of B.L. guns.—Table for gravimetric density of charge.

THERE are two points to be considered in connection with the power of artillery, viz.: the work impressed on the projectile, and the work done upon the gun. **Work.**

A gun may be looked upon as a machine for throwing destructive projectiles to a considerable distance, so its power may clearly be measured by the effect of a given nature of projectile at a definite range. **Power.**

Power it must be remembered, is independent of construction; but with similar pieces of ordnance, that which can produce the greatest effect with certainty and regularity in the shortest space of time, would naturally be pronounced the best gun. On the other hand, it is evident that in producing these effects the gun must not be unduly strained; and for comparison of different pieces of ordnance the stress thrown on the gun in each case should be equal, or at any rate proportional to the ballistic results. **Power independent of construction.**

Accordingly it is the practice in the Royal Gun Factory, on bringing out any new piece, to ascertain the maximum velocity which can be imparted to the shot with a charge best suited to the gun; afterwards the range and accuracy of shooting are practically determined at Shoeburyness. Range with similar projectiles will depend mainly upon **M.V., range, and accuracy.**

CHAP. IV. initial velocity, and accuracy upon a low trajectory with steadiness of flight; so with service projectiles, the power may be said to depend on muzzle velocity, and this again on the amount of the charge which can be used within limits of pressure. Complete combustion of the charge and the degree of resistance in the bore are also matters for consideration, for these points help to determine the maximum effect which can be produced with a minimum expenditure of stores.

Object of fire. The first point in connection with "power" is the *object* that is sought to be attained by any particular nature of fire. We may resolve this question into three general cases:—

Field Artillery. (1) Field Artillery; when power may be said to be proportionate to the range and effect of various natures of shell, especially against troops in the field. The power of shrapnel shell is generally measured by the number of *effective* bullets or splinters which can strike within a given area; the greater the range at which a definite effect of this kind can be produced, the more powerful a field gun is considered. The range, *cæteris paribus*, depends on the initial velocity of the shell, and so does flatness of trajectory, which mainly ensures accurate shooting; so we must decide first on the minimum velocity that is necessary to give to the bullets sufficient energy for disabling a man,* and this will determine the range of the gun. Since this kind of power chiefly depends on velocity, it is the muzzle velocity which is studied in the manufacture of a gun of this class, in conjunction of course with the internal pressure which limits the strain on the piece.

Siege ordnance. (2) Siege Ordnance. In this case, power generally will depend upon the capacity of common shell. A siege gun is required to break down earthworks, destroy masonry, and search out buildings, &c., behind cover. The projectile should, therefore, have sufficient energy to penetrate deeply into the object of fire, and then bursting it should wreck the spot as if a mine had exploded. Hence velocity again is required for range and penetration of shell, but the size and capacity of the shell is perhaps in this case as important. In the transport of ordnance for any siege purpose weight of course must be specially considered, so when this and the dimensions of the shell have been fixed, it is the aim of the manufacturer to construct a piece which shall give to these projectiles the highest velocity within its proper limits of strength.

Heavy guns. (3) Heavy guns. These are used for many natures of fire, but they are only required to put forth their full strength in effecting the perforation of armour. This kind of power, with projectiles of the same form, material, and weight, will be found to vary with some function of the striking velocity of the shot. Penetration of wrought-iron plate will be discussed in a later part of this chapter, but velocity again is evidently the chief element of power in this subdivision of ordnance.

Hence velocity is of primary importance for all natures of projectiles, and it will be necessary to explain the method of ascertaining the muzzle velocity of a shot as observed at the Royal Gun Factory; afterwards we can investigate the retardation in air to obtain the striking velocity, which is the real measure of power or destructive effect.

Various instruments have been used in the history of artillery to measure the velocity of a shot, such as the Ballistic Pendulum;

* Colonel Maitland, R.A., in a paper which was published in the Proceedings, R.A. Institution, vol. ix, p, 384, estimated that the remaining velocity in shrapnel shell should be not less than 800 f.s.; but probably, 500 f.s. striking velocity would be amply sufficient for a bullet or splinter of size to kill or disable a man.

the Navez-Leurs Electric Machine; the Noble Chronoscope; and the Boulengè, Bashforth and Watkin Chronographs; but the only one employed of late years is the Boulengè Chronograph, so it will be sufficient to give a general description of this instrument in use.*

The Boulengè Chronograph.

Boulengè chronograph.

Electricity is the agent employed for obtaining records to correspond with the motion of a projectile in the air. The apparatus consists of two parts, viz.: (1) a mechanical instrument, and (2) a system of electrical circuits.

The instrument is a hollow brass column carrying two electro-magnets attached at different heights; the column stands on a triangular base resting on three fine-threaded screws, so that it may be accurately adjusted in a vertical position.

From the upper magnet a long bar called a "chronometer" can be suspended when a current of electricity is passing through the coil: from the lower a short bar called the "registrar" can be hung in a similar manner. Beneath the latter a table is placed on which the registrar falls as soon as the electric current ceases to flow, and a guard-tube is provided to catch it after striking the table: the table is connected with a circular knife, which can be held back by a spring-catch, and this is released by a "trigger" arrangement when the falling-weight drops on the table. The chronometer is sheathed with a zinc tube (to be renewed as often as necessary) in order that the knife may make a perceptible mark when it strikes.

Action of the instrument.

Now suppose the circuits to be completed, the magnets to be active, and both bars to be suspended from their points of attachment; if the *registrar alone* is permitted to fall it will evidently make a dent on the chronometer on a level with the edge of the knife: this point may be called the "origin" or "zero" on the bar, for the measurement of distance of other points afterwards marked above it. Again, supposing *both bars to be released simultaneously;* the chronometer will then fall a certain height before the knife comes in contact with the zinc tube, because time is required for the registrar to act and for the knife to strike after release; the time is fixed at ·15 of a second, and the adjustment for time must always be carefully made before using one of these instruments. The point marked in this case on the chronometer is called the "Disjunctor reading," for the instrument should read to this line when by means of a disjunctor in the electrical circuits both currents are severed at once.

As a third case let us imagine that a short space of time is allowed to elapse between the moments of releasing the bars, *the chronometer being allowed to fall first*; it is evident now that the mark made on the zinc will be registered still higher up, the height varying with the time which is allowed to lapse in giving the chronometer a start. In this lies the principle of the Boulengè chronograph for measuring

* Colonel Sebert's velocimeter has been recently added to the instruments at the Proof Butts. This is an ingenious machine by which the vibrations of a tuning fork are made to record the velocity of a shot between any two points in its path. The note of the fork is pitched to give exactly 1,000 vibrations per second, and these can be marked on a strip of steel coated with lamp-black, while an axis line is being drawn at the same time by a fixed pen. Electrical currents are arranged to indicate the passage of the shot from point to point, and the number of vibrations recorded between the corresponding positions on the steel strip is a measure of the velocity of the shot over that interval, which may be either in the gun or in front of the muzzle. This instrument can be used to measure recoil, and also by calculation to find out the pressure at any part in the bore.

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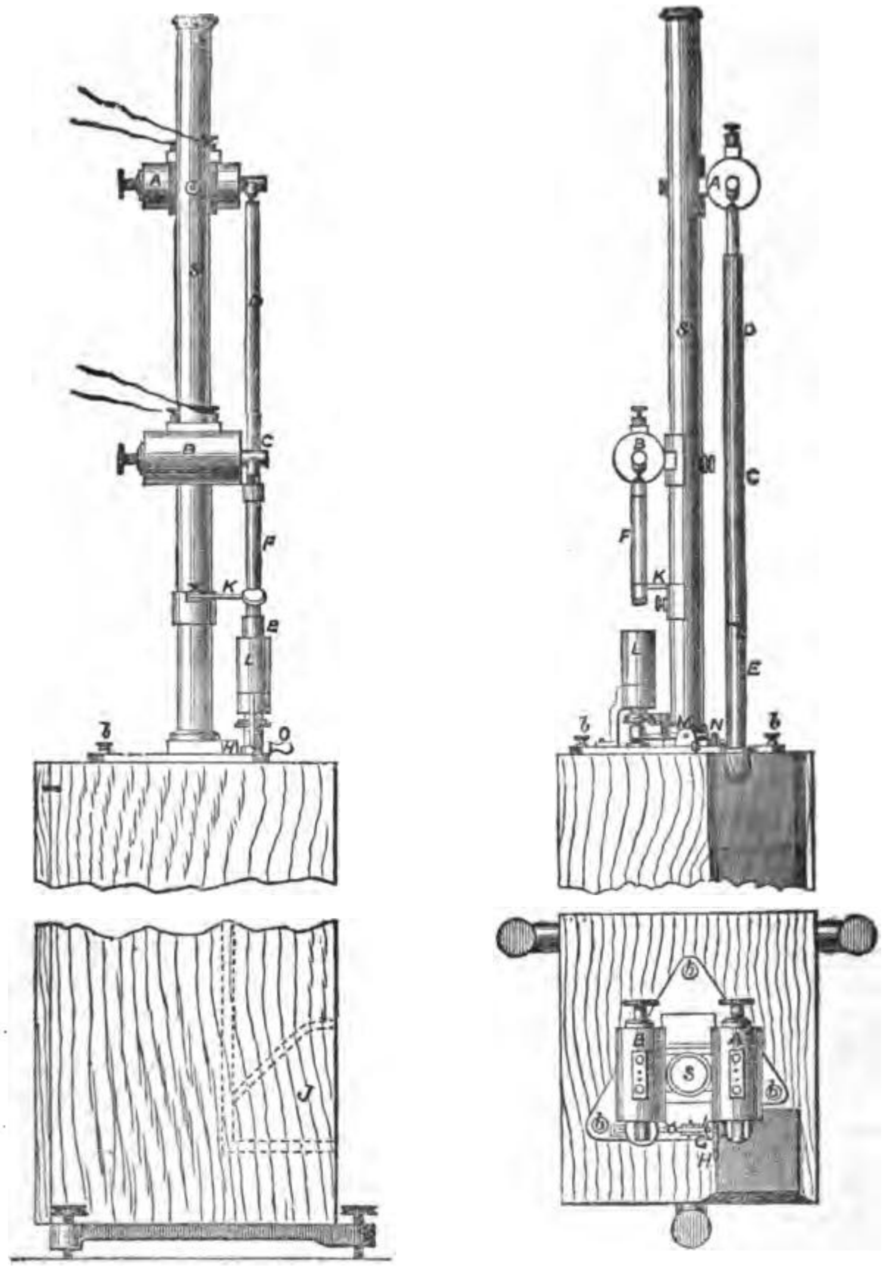
Fig. 1.—Chronograph in position for measuring the velocity of projectiles.

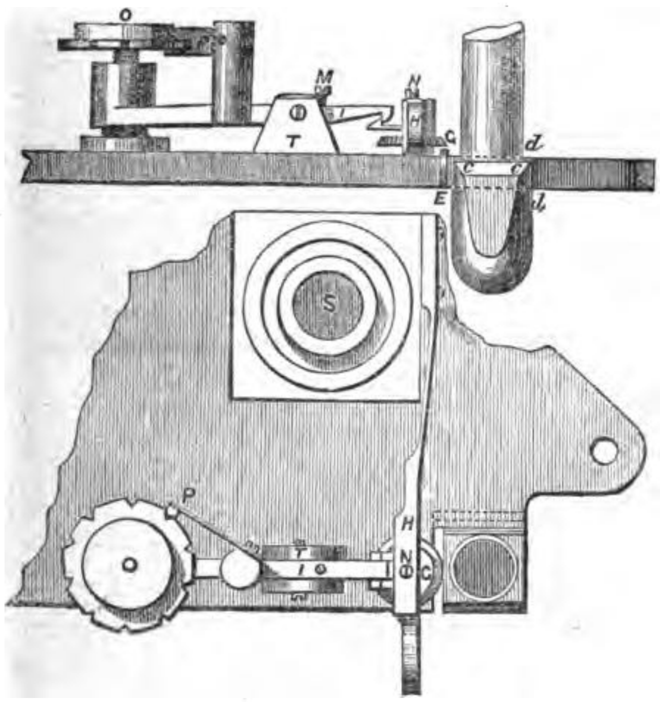
Side view from the left. **Front view.**



Horizontal projection.

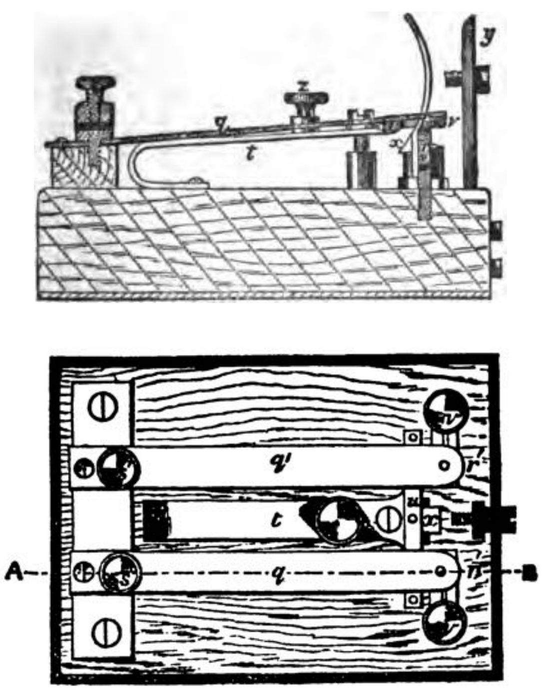
S. The brass column.	*G*. Circular knife.
A and *B*. Electro-magnets.	*H*. A spring.
C. The chronometer.	*K*. A steadying bracket.
D and *E*. Zinc tubes.	*L*. The guard tube.
F. The registrar.	*b b*. Adjusting screws.

Fig. 2.—The Trigger.



I. Lever.
M. Screw for regulating the hold of the catch.
N. Screw for circular knife.
O. The table.
P. Pawl for regulating the height of table.
T. Trigger stand.

Fig. 3.—The Disjunctor.



t. Mainspring.
u. Cross-piece.
q q. Spring plates.
r r. Metal pins.
s s., *v v.* Binding screws for the wires.
x. Catch for mainspring.
z. Stud for mainspring.

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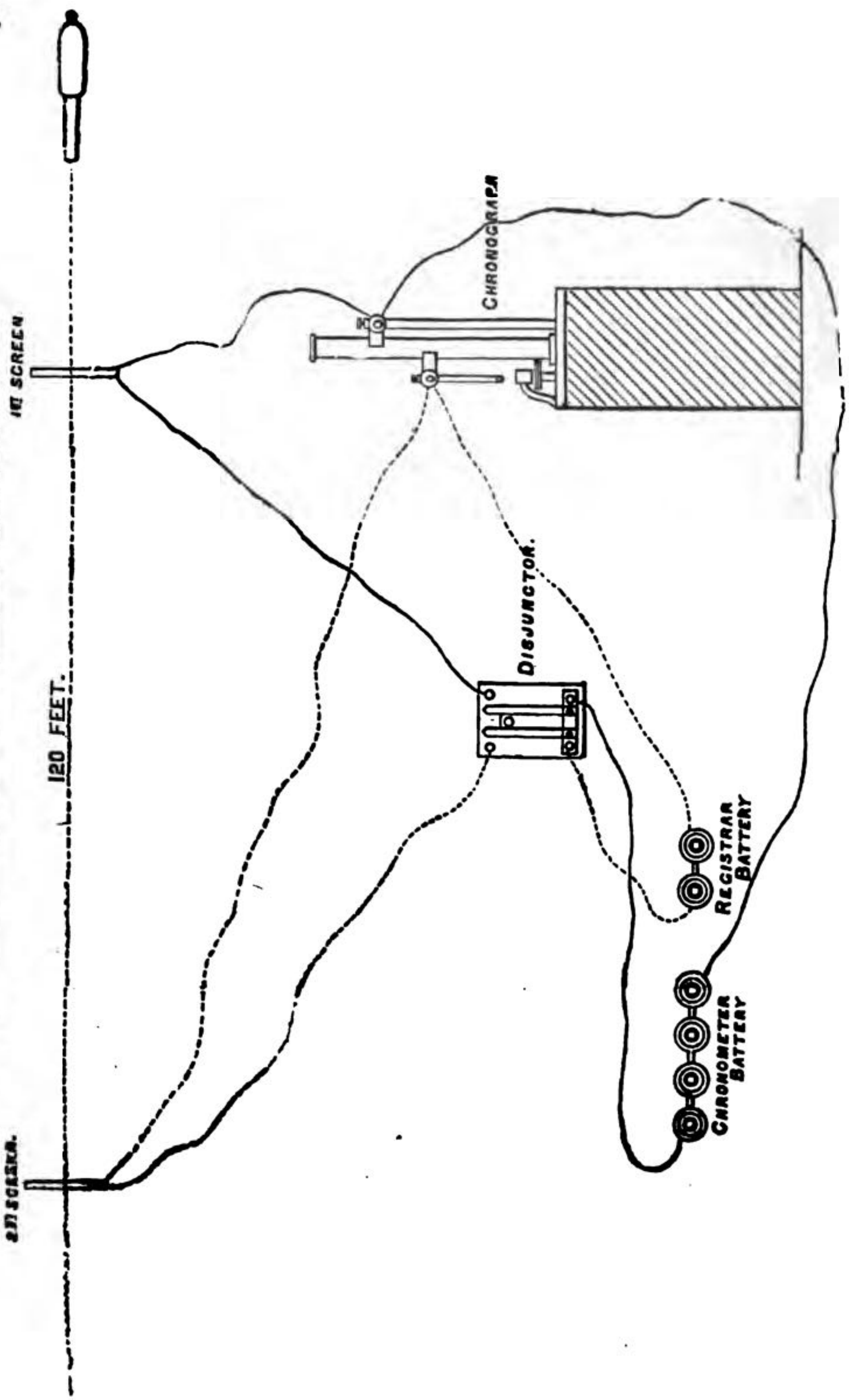

FIG. 4.—GENERAL ARRANGEMENT OF THE CHRONOGRAPH AND SCREENS, &C.

N.B.—The instruments are enlarged out of scale to show the details; the instrument room must be some distance away from the proof-ground.

CHAP. IV.

velocity in a shot; it is a *gravity* instrument, and the height of the "velocity mark" upon the chronometer above the disjunctor line is a measure of the time which has elapsed between the successive interruptions of the currents.

Electric circuits. The electric circuits consist of two separate batteries, the number of cells being proportional to the strength which is required in the magnets. The more powerful battery is connected with the upper magnet, which has to support the longer and heavier bar (the chronometer), and this is connected with a wooden frame laced across with copper wire in the circuit, placed a short distance from the muzzle of the gun.* The other battery in a similar manner supplies a current for the lower magnet and a second screen which is placed in the path of the shot at a definite distance in front of the first.

Mode of use. On firing the gun, the shot passes through both the screens and breaks the wires successively; then the interval of time between the interruption of the two circuits, which is the time taken by the shot in passing over a definite space, is measured by the height through which the chronometer falls under the simple action of gravity.

The screens are usually placed 120 feet apart, the one nearest the gun being sufficiently far from the muzzle to avoid injury from the blast, or pellets of unconsumed powder.

The heights on the chronometer will be measured by scale, and the corresponding velocities may be read off from a table, or from graduations on the same scale. An example will show how velocity may be arrived at from any measured height on the chronometer bar.

Example. Let the height $h = 8{\cdot}573$ inches through which the chronometer has fallen, measured from the origin or zero. Then, since $h = \frac{1}{2}gt^2$,

$$t = \sqrt{\frac{2h}{12 \times g}} = \sqrt{\frac{8{\cdot}573}{6 \times g}} = {\cdot}2107 \text{ of a second.}$$

Deduct ·15 of a second for the instrument, and ·0607 is the time taken by the shot in passing over the space between the two screens. It follows then from the ratio $\frac{\text{space}}{\text{time}}$, which is the common expression for rate of motion, that the velocity $= \frac{120}{{\cdot}0607} = 1977$ f.s.

Adjustment. It has been mentioned already that the instrument requires careful adjustment. There are three points to be looked to invariably just before use:—

(1) The vertical position of the column; this can be regulated by the pedestal-screws when the chronometer is suspended in proper position.

(2) The strength of the magnets; this adjustment is made by a small brass cylinder which can be slipped over the bars, and which the electro-magnets must *not* be able to support in addition to the weight of the rods. Daniel's cells are commonly used, because it is important to have a current of constant intensity.

(3) The disjunctor reading; this must be carefully attended to, and its adjustment will require further explanation.

Disjunctor reading. On the graduated rule which is supplied for measuring the heights and velocities, both a zero and a disjunctor line will be found, the latter

* The wire is often stretched across the muzzle of the gun with proper insulating means of attachment, but the moveable screen is generally found most convenient.

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being marked at a distance from zero equivalent to the height which the chronometer would fall in ·15 of a second, viz.:—4·345 inches. By means of a scriber attached to a vernier-slide on the scale, a line representing this distance can be traced all round the zinc tube, which for economy is put on in two lengths, for each can be reversed or exchanged independently when too much marked for further use. Both currents are brought under control by passing them through a "disjunctor:" this is a detached part of the instrument composed of a mainspring, with a cross-piece of some insulating material, between two steel plates which form part of the circuits. When the spring is pressed under a catch the steel plates are brought in contact with two metal pins, so that the electrical circuits are then complete. When the spring is released, the crosspiece (striking both the steel plates at once) lifts them away from the pins, and so breaks both the currents at the same instant exactly.

It is of the utmost importance that the disjunctor reading should agree with the line marked on the chronometer bar. To effect this, the disc of the trigger on which the registrar falls is made capable of being raised or lowered within certain limits so as to regulate the time of its fall; this will have to be adapted to the strength of the currents, length of wire in the circuits, and other variable quantities affecting the time required for the instrument itself.

There remain still one or two points to be noticed in connection with the Boulengè chronograph to adapt it for use when the standard conditions cannot be conveniently followed.

Change of distance between the screens.

It may sometimes be convenient to change the distance between the two screens. In this case the mode of procedure is exactly the same, and the same graduated rule may be used; for since the instrument merely measures the *time*, velocity will be directly proportionate to the interval between the two screens.

For example, let the distance be changed from 120 to 60 feet, and let v' be the velocity read off from the scale; then

$$v : v' :: 60 : 120$$

$$v = \frac{60}{120} v'$$

or, as a general expression, $v = \frac{S}{120} v'$

Change of time in the instrument.

The time of the instrument's action may also be changed by fixing the electro-magnets nearer or farther apart. Such an alteration, however, will affect the disjunctor reading, for this line would have to be traced at a height corresponding to the new time. Suppose, for instance, that any one wished to allow the instrument more time, say ·2 of a second instead of ·15, the height of the disjunctor reading would then be 7·724 inches, and a special velocity scale would be needed; but calculations could always be made from first principles, by means of a scale reading to a thousandth of an inch.

Flat-headed projectiles.

Flat-headed projectiles are always used at the Proof Butts, to make sure of breaking a strand in each screen; their penetration into sand is much less than that of an ogival-headed shot, while uncertainty of deflexion is also avoided to a very great extent.

Muzzle Velocity.

Observed velocity.

The velocity obtained by use of the Boulengè chronograph is a mean velocity between the two screens; but as the retardation of the

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projectile in air over so short a space would be small, we may practically take the observed velocity as the actual velocity at the *middle point* between the two screens. This is a point in the path of the shot some distance from the muzzle of the gun, so the next step of calculation will be to find the velocity at the muzzle. By the same formulæ that enable us to work back to the muzzle, we can also determine the remaining velocity at any definite range.

It is acknowledged that the retardation of a shot is some function of its velocity, depending also on the dimensions and weight of the projectile $\left(i.e., \propto \frac{d^2}{w}\right)$, and on the form of its head.

Cubic law of resistance.

Bernoulli, in the early part of last century, first propounded the cubic law of resistance, and established by mathematical reasoning that retardation varied with some function of this power of the velocity, that is to say, that $R = \mu v^3$, where μ is a quantity depending on special conditions. This may not be perfectly true for all velocities, high and low, but it was the foundation of Mr. Bashforth's experiments, and of the tables which are now generally used. We cannot afford space to investigate here the motion of a projectile in air,* but, accepting this law of resistance, it may be advisable just to explain how the value of μ was obtained for elongated projectiles of service dimensions.

Laws of motion.

Velocity when uniform is measured by the ratio of space to time, thus $v = \frac{s}{t}$. When variable $v = \frac{ds}{dt}$. Hence the law of motion which connects space and time with acceleration or change in the motion, is given by the equation $f = \frac{dv}{dt} = \frac{d^2s}{dt^2}$, where f denotes acceleration.

Now Mr. Bashforth conceived that if the time of flight of a shot was expressed differentially in terms of the space, and if the second differentiations became practically constant, the motion of a projectile in air would be connected at once with these known mathematical laws. Thus, if

$$t = as + bs^2.$$

$$\frac{dt}{ds} = a + 2bs.$$

$$\text{and } v \text{ or } \frac{ds}{dt} = \frac{1}{a + 2bs}$$

$$\text{hence } \frac{d^2s}{dt^2} = -\frac{2b\,\frac{ds}{dt}}{(a + 2bs)^2} = -\,2bv^3.$$

Here we have the cubic law of resistance, and the problem to be practically solved was, first, whether $2b$ could be considered as constant, and, if so, what value should be assigned to this quantity in the case of projectiles of service dimensions.

Bashforth's experiments.

Mr. Bashforth accordingly invented a chronograph which could be used with any number of screens, and he carried out exhaustive

* For a complete investigation of trajectories the reader is referred to Mr. Bashforth's work on this subject, and to a pamphlet by Professor Niven, F.R.A.S., "On the calculation of the Trajectories of Shot," which was published by the Royal Society in 1877. Both methods of investigation have been set forth in the "Text Book of Gunnery," 1883, by Captain Mackinlay, R.A.; and more recently Professor Greenhill, M.A., has supplied a new method of treating this subject in a paper which was published in the Proceedings of the R.A. Institution in August, 1884.

CHAP. IV. experiments to ascertain the loss of velocity or retardation at successive points in the path of a shot. It was found with a 12-pr. (3-inch) gun that to nine places of decimals $2b$ might be taken as constant and equal to ·000000084.*

Coefficient of retardation.

Retardation, however, must evidently vary directly with the area presented to the resistance of the air, and inversely with the weight of the projectile of any given diameter. Hence $R \propto \frac{d^2}{w}$; and to find the value of $2b$ in the case of any other gun, say the 9-inch R.M.L. gun,

$$2b = \cdot000000084 \times \frac{(8\cdot92)^2}{250} \times \frac{11\cdot6}{(2\cdot95)}$$
$$= \cdot00000003447.$$

Retardation will vary also to some extent with the form of head on the projectile, with the state of the atmosphere, &c.; the effects of which altogether Mr. Bashforth summed up in an infinitesimal quantity K, varying with different velocities; and this he multiplied by $(1000)^3$ to give it a tabular value. In using his tables, therefore, we must write $2b = \frac{d^2}{w} \cdot \frac{K}{(1000)^3}$.

Formulæ for space and time.

Adapting this expression to the law of retardation caused by resistance in air, we find that $f = \frac{d^2s}{dt^2} = -2bv^3 = -\frac{d^2}{w} \cdot -\frac{d^2}{w} \cdot K\left(\frac{v}{1000}\right)^3$.

Assuming that the force of resistance acts always in the direction of flight, that is to say, in a tangent to the curve of the trajectory; and that, with low trajectories and high velocities, the path of a shot over a limited space may be considered as a straight horizontal line (the vertical component being neglected); then since $\frac{d^2s}{dt^2} = \frac{dv}{dt} = -2bv^3$, we find by integration between the limits of any two adjacent velocities V_1 and V_2 that $2bt = \frac{1}{2}\left\{\frac{1}{V_1^2} - \frac{1}{V_2^2}\right\}$,

and since $\frac{dv}{dt} = v\frac{dv}{ds}$ we find also that $2bs = \left\{\frac{1}{V_1} - \frac{1}{V_2}\right\}$.

By substituting in these equations the value of b as given in the expression above we arrive at the following formulæ:—

$$\frac{d^2}{w}t = \frac{500}{K}\left\{\left(\frac{1000}{V_1}\right)^2 - \left(\frac{1000}{V_2}\right)^2\right\} \quad . \ . \ . \ . \quad (A)$$

$$\text{and } \frac{d^2}{w}s = \frac{(1000)^2}{K}\left\{\frac{1000}{V_1} - \frac{1000}{V_2}\right\} \quad . \ . \ . \ . \quad (B)$$

Integrals.

These quantities have been integrated for small differences of velocity, commencing with an initial velocity of 1,700 f.s., and assuming a retardation of 10 f.s. at a time, giving the proper value to K in each calculation. The table of integrals thus carefully compiled was afterwards rendered complete by interpolation for each foot per second. The calculations were no doubt intricate, but the use of these tables (like a table of logarithms) has been made very simple. By means of symbols for these tabulated quantities the foregoing expressions may be written as follows:—

* From subsequent experiments with higher and lower velocities, it appears that b is subject to considerable variation.

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Formulæ for the old tables.

$$\left.\begin{aligned}\frac{d^2}{w}t &= T_v - T_V \\ \frac{d^2}{w}s &= S_v - S_V\end{aligned}\right\}\text{for the tables published in 1870.}$$

where T_v and S_v refer to any observed or remaining velocity v, and T_V S_V to the initial or muzzle velocity V. Then in using these formulæ for working examples, a problem is reduced to the solution of a simple equation, with only one quantity unknown.

Extension of tables.

With the introduction of high velocity guns it was found necessary to extend these tables considerably, so Mr. Bashforth repeated his experiments in 1878–9. A new set of tables were published in 1880, which are entirely different from those published before; for certain changes were introduced to render them more simple and accurate, and these integrals form a perfectly new series of numbers. The formulæ also were changed; they are now written as follows:—

Formulæ for the new tables.

$$\left.\begin{aligned}\frac{d^2}{w}t &= T_V - T_v \\ \frac{d^2}{w}s &= S_V - S_v\end{aligned}\right\}\text{for the tables of 1880.}$$

Before working an example it is necessary to ascertain which tables are available for use. The new tables are given at p. 80, and they are used in the following examples, which are intended to show some of the ways in which the formulæ can be applied.

Examples.

I. The observed velocity of a shot from a 12-pr. B.L. gun at 110 feet from the muzzle is 1,780 f.s. To find the muzzle velocity.

I. Muzzle-velocity.

Here $d = 3$ inches; $w = 12{\cdot}5$ lb.; $s = 110$ feet; and $v = 1780$.

Hence $\frac{d^2}{w}s = 79{\cdot}2$.

Then since

$$\frac{d^2}{w}s = S_V - S_v$$

$$\begin{aligned}S_V = S_v + \frac{d^2}{w}s &= S_{1780} + 79{\cdot}2 \\ &= 44360{\cdot}5 + 79{\cdot}2 \\ &= 44430{\cdot}7.\end{aligned}$$

Now, by examining the tables for a velocity which corresponds to this number, we find that

$$V = 1{,}800 \text{ f.s.}$$

Correction for flat-headed projectile.

If a flat-headed projectile was used and the corresponding velocity is required for one of ogival form, the amount of correction to the observed velocity will be about double, and then M.V. would be 1,820 f.s.*

II. Time of flight.

II. In what time would the velocity of the projectile be reduced from 1,820 to 800 f.s.?

Taking the formula for "time" and substituting the values of d and w, as before—

* This rule for correction has been in force for some time; it was recently tested by a series of experiments conducted at Woolwich and Shoeburyness, and proved to be perfectly right.

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$$t = \frac{12{\cdot}5}{9}(T_{1820} - T_{800})$$
$$= 1{\cdot}39\,(233{\cdot}1353 - 225{\cdot}7685)$$
$$= 1{\cdot}39 \times 7{\cdot}3668$$
$$= 10{\cdot}24 \text{ seconds.}$$

III. Range for remaining velocity.

III. What would be the range in the preceding case

$$s = \frac{w}{d^2}\left\{S_V - S_v\right\}$$
$$= 1{\cdot}39\,\{\,44520{\cdot}3 - 36512\,\}$$
$$= 1{\cdot}39 \times 8007{\cdot}7$$
$$= 11{,}130 \text{ feet.}$$
$$= 3{,}710 \text{ yards.}$$

These examples may be taken to show the effective range and extreme length of fuze for shrapnel shell when fired from this nature of gun, assuming that the shell ought to possess a remaining velocity of 800 f.s. at the time of disruption.

IV. Range for observed time of flight.

IV. A shot is fired towards an enemy's work from a 22-pr. gun to find out the range, and it is observed to strike the ground in five seconds. Show how the distance may be ascertained.

N.B.—There is no formula directly combining the data for space and time, so we have to work through a connecting link, which is found in "remaining velocity."

We have here for the data: M.V. (say) 1,790 f.s.; $d = 3{\cdot}5$ inches; $w = 22$ lb.; $t = 5$ seconds; and $\frac{d^2}{w}t = 2{\cdot}785$.

(1) To find the striking velocity:—

$$\frac{d^2}{w}t = T_V - T_v$$
$$T_v = T_{1790} - 2{\cdot}785$$
$$= 233{\cdot}0690 - 2{\cdot}785$$
$$= 230{\cdot}284;$$

hence $v = 1{,}068$ f.s.

(2) To find the range:—

$$\frac{d^2}{w}s = S_V - S_v$$
$$s = \frac{w}{d^2}\left\{S_{1790} - S_{1068}\right\}$$
$$= \frac{22}{(3{\cdot}5)^2}\left\{44400{\cdot}7 - 40632{\cdot}6\right\}$$
$$= \frac{22 \times 3768{\cdot}1}{(3{\cdot}5)^2}$$
$$= 6{,}766 \text{ feet,}$$
$$= 2{,}255 \text{ yards.}$$

Trajectory for high-angle fire.

It has now been explained how velocity at the muzzle may be found from the mean velocity observed by a chronograph, and how by similar calculation the shot's velocity may be known at a distance; thence also how range and time of flight may be found. But these calculations are applicable only to flat trajectories, that is to say, to direct fire; with high angles of elevation it becomes necessary to work

out the trajectory in parts, by dividing the curve into several portions, at any rate into an ascending and descending branch. This is laborious work, and not generally undertaken, except for scientific research.

Angle of descent.

Angle of descent.

From a complete trajectory the angle of descent would naturally be found, and this is a useful point in connection with high-angle fire; but for low angles of elevation a short method of calculation can be given in terms of the component parts of velocity.

If we take ϵ and ϕ as the angles of elevation and descent,

$$\tan \epsilon = \frac{\text{vertical velocity}}{\text{horizontal velocity (initial)}},$$

$$\text{and } \tan \phi = \frac{\text{vertical velocity}}{\text{horizontal velocity (final)}}$$

Now with small angles we may consider that the value of the tangent is proportional to that of the angle itself, and with a flat trajectory there can be little change in the vertical component of velocity; therefore—

$$\frac{\epsilon}{\phi} = \frac{\tan \epsilon}{\tan \phi} = \frac{v}{V}$$

$$\text{and } \phi = \frac{V}{v}\epsilon.$$

Example.

For example, let us take the 6·3-inch R.M.L. howitzer fired with a 4 lb. charge at an elevation of about 4 degrees. The M.V. with this charge is 750 f.s., and the range about 800 yards. We must first calculate the remaining velocity:—

$$\begin{aligned} S_v &= S_{750} - \frac{(6{\cdot}3)^2\, 2400}{70} \\ &= 35440{\cdot}2 - 1360 \\ &= 34080{\cdot}2 \\ \text{whence } v &= 692 \text{ f.s.} \end{aligned}$$

Now for the angle of descent:—

$$\begin{aligned} \phi &= \frac{V}{v}\epsilon = \frac{750}{692}4^\circ \\ &= 4{\cdot}336 = 4^\circ\, 20' \text{ approx.} \end{aligned}$$

A small correction might have to be given for "jump," which practically makes a change in the elevation of the gun; this varies with different systems of mounting.

This method, however, is now generally superseded by that of Mr. W. D. Niven, whose Table (with an example of its application) is given in the Appendix, p. 383.

The following tables for calculation of velocity and time are reprinted from Mr. Bashforth's Report on Experiments made with his Chronograph, 1880:—

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TABLE VI.

Table of Values of $\frac{d^2}{w}t$ for Ogival-headed Shot.

v	0	1	2	3	4	5	6	7	8	9	Diff.
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	+
10	75·399	77·111	78·790	80·437	82·052	83·636	85·190	86·715	88·212	89·682	1·584
11	91·125	92·542	93·934	95·301	96·644	97·964	99·261	*00·536	*01·789	*03·021	1·320
12	1 04·232	05·423	06·595	07·748	08·883	09·999	11·097	12·178	13·243	14·291	1·116
13	1 15·323	16·339	17·340	18·326	19·297	20·254	21·196	22·124	23·039	23·941	·957
14	24·830	25·706	26·570	27·422	28·262	29·091	29·908	30·714	31·509	32·294	·829
15	33·068	33·832	34·586	35·331	36·066	36·792	37·508	38·215	38·913	39·602	·726
16	1 40·283	40·955	41·618	42·273	42·920	43·559	44·190	44·813	45·429	46·038	·639
17	46·640	47·235	47·823	48·404	48·978	49·546	50·107	50·662	51·211	51·754	·568
18	52·291	52·822	53·347	53·867	54·381	54·890	55·393	55·890	56·382	56·869	·509
19	1 57·351	57·828	58·300	58·767	59·229	59·686	60·138	60·586	61·029	61·468	·457
20	61·902	62·332	62·758	63·180	63·598	64·012	64·422	64·828	65·230	65·628	·414
21	66·022	66·412	66·798	67·181	67·560	67·936	68·308	68·676	69·041	69·403	·376
22	1 69·762	70·118	70·470	70·819	71·165	71·508	71·848	72·185	72·519	72·850	·343
23	73·179	73·505	73·828	74·148	74·465	74·780	75·092	75·401	75·708	76·012	·315
24	76·314	76·613	76·909	77·203	77·494	77·783	78·070	78·354	78·636	78·916	·289
25	1 79·194	79·470	79·743	80·014	80·283	80·550	80·815	81·078	81·339	81·598	·267
26	81·855	82·110	82·363	82·614	82·863	83·110	83·355	83·598	83·839	84·079	·247
27	84·317	84·553	84·787	85·020	85·251	85·481	85·709	85·935	86·160	86·382	·230
28	1 86·604	86·824	87·042	87·259	87·474	87·688	87·900	88·111	88·320	88·528	·214
29	88·734	88·939	89·143	89·345	89·546	89·745	89·943	90·140	90·335	90·529	·199
30	90·721	90·912	91·102	91·291	91·478	91·664	91·849	92·033	92·216	92·397	·186
31	1 92·577	92·756	92·934	93·111	93·287	93·461	93·634	93·806	93·971	94·147	·174
32	94·316	94·484	94·651	94·817	94·982	95·146	95·309	95·471	95·632	95·792	·164
33	95·951	96·109	96·266	96·422	96·577	96·731	96·884	97·036	97·187	97·338	·154
34	1 97·488	97·637	97·785	97·932	98·078	98·223	98·367	98·510	98·652	98·794	·145
35	98·935	99·075	99·214	99·352	99·490	99·627	99·763	99·898	*00·032	*00·166	·137
36	2 00·299	00·431	00·562	00·692	00·822	00·951	01·079	01·206	01·333	01·459	·129
37	2 01·585	01·710	01·834	01·957	02·080	02·202	02·323	02·443	02·563	02·682	·122
38	02·801	02·919	03·036	03·152	03·268	03·383	03·497	03·610	03·723	03·836	·115
39	03·947	04·058	04·168	04·278	04·387	04·496	04·604	04·711	04·818	04·924	·109
40	20 5·0299	5·1349	5·2393	5·3432	5·4466	5·5494	5·6517	5·7534	5·8546	5·9553	·1028
41	6·0554	6·1550	6·2540	6·3525	6·4505	6·5480	6·6450	6·7414	6·8373	6·9327	·0975
42	7·0276	7·1220	7·2159	7·3093	7·4022	7·4947	7·5867	7·6782	7·7693	7·8599	·0925
43	20 7·9501	8·0398	8·1291	8·2179	8·3063	8·3942	8·4817	8·5687	8·6553	8·7415	·0879
44	8·8272	8·9125	8·9974	9·0819	9·1660	9·2497	9·3330	9·4159	9·4984	9·5805	·0837
45	9·6622	9·7435	9·8244	9·9050	9·9852	*0·0651	*0·1446	*0·2237	*0·3025	*0·3809	·0799
46	21 0·4590	0·5367	0·6140	0·6910	0·7677	0·8440	0·9200	0·9956	1·0709	1·1459	·0763
47	1·2205	1·2948	1·3687	1·4423	1·5156	1·5886	1·6613	1·7336	1·8056	1·8773	·0730
48	1·9487	2·0198	2·0906	2·1611	2·2313	2·3012	2·3708	2·4401	2·5091	2·5779	·0699
49	21 2·6464	2·7146	2·7825	2·8501	2·9174	2·9845	3·0513	3·1178	3·1841	3·2501	·0671
50	3·3159	3·3814	3·4466	3·5116	3·5763	3·6606	3·7050	3·7689	3·8326	3·8960	·0645
51	3·9592	4·0221	4·0848	4·1472	4·2094	4·2713	4·3330	4·3944	4·4556	4·5165	·0619
52	21 4·5772	4·6377	4·6979	4·7579	4·8177	4·8773	4·9367	4·9958	5·0547	5·1134	·0596
53	5·1719	5·2302	5·2882	5·3460	5·4036	5·4610	5·5182	5·5752	5·6320	5·6886	·0574
54	5·7450	5·8012	5·8572	5·9130	5·9686	6·0240	6·0792	6·1342	6·1890	6·2436	·0554
55	21 6·2980	6·3522	6·4062	6·4600	6·5136	6·5670	6·6202	6·6732	6·7260	6·7786	·0534
56	6·8311	6·8834	6·9355	6·9874	7·0391	7·0907	7·1421	7·1933	7·2444	7·2953	·0516
57	7·3460	7·3965	7·4469	7·4971	7·5471	7·5970	7·6467	7·6962	7·7456	7·7948	·0499
58	21 7·8438	7·8928	7·9417	7·9904	8·0389	8·0873	8·1356	8·1837	8·2316	8·2793	·0483
59	8·3271	8·3746	8·4220	8·4692	8·5163	8·5632	8·6100	8·6566	8·7031	8·7494	·0468
60	8·7957	8·8417	8·8877	8·9334	8·9791	9·0246	9·0700	9·1152	9·1603	9·2052	·0454
61	21 9·2501	9·2947	9·3393	9·3837	9·4280	9·4721	9·5161	9·5600	9·6037	9·6473	·0441
62	9·6908	9·7341	9·7773	9·8204	9·8633	9·9062	9·9489	9·9914	*0·0338	*0·0761	·0428
63	22 0·1183	0·1604	0·2023	0·2441	0·2858	0·3273	0·3687	0·4100	0·4512	0·4922	·0415
64	22 0·5332	0·5740	0·6147	0·6552	0·6957	0·7360	0·7762	0·8163	0·8563	0·8962	·0403
65	0·9359	0·9755	1·0151	1·0544	1·0937	1·1328	1·1718	1·2107	1·2495	1·2881	·0391
66	1·3267	1·3651	1·4034	1·4416	1·4797	1·5177	1·5555	1·5933	1·0309	1·6684	·0379
67	22 1·7059	1·7432	1·7804	1·8175	1·8545	1·8914	1·9281	1·9648	2·0014	2·0378	·0368
68	2·0742	2·1105	2·1466	2·1827	2·2186	2·2545	2·2902	2·3259	2·3614	2·3969	·0358
69	2·4322	2·4675	2·5027	2·5377	2·5727	2·6076	2·6424	2·6771	2·7117	2·7462	·0348

Table of Values of $\frac{d^2}{w}t$ for Ogival-headed Shot.

v.	0	1	2	3	4	5	6	7	8	9	Diff.
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	+
70	22 2·7806	2·8150	2·8492	2·8833	2·9174	2·9513	2·9852	3·0189	3·0526	3·0862	·0339
71	3·1196	3·1530	3·1863	3·2195	3·3526	3·2856	3·3185	3·3513	3·3840	3·4167	·0330
72	3·4492	3·4816	3·5140	3·5462	3·5784	3·6105	3·6424	3·6743	3·7061	3·7378	·0320
73	22 3·7694	3·8009	3·8323	3·8636	3·8949	3·9260	3·9571	3·9881	4·0189	4·0497	·0311
74	4·0804	4·1110	4·1416	4·1720	4·2024	4·2326	4·2628	4·2929	4·3230	4·3529	·0302
75	4·3828	4·4125	4·4422	4·4719	4·5014	4·5308	4·5602	4·5895	4·6187	4·6478	·0294
76	22 4·6769	4·7058	4·7347	4·7635	4·7922	4·8208	4·8483	4·8777	4·9060	4·9343	·0286
77	4·9624	4·9905	5·0185	5·0464	5·0742	5·1020	5·1296	5·1572	5·1847	5·2121	·0277
78	5·2394	5·2666	5·2937	5·3208	5·3478	5·3747	5·4015	5·4282	5·4549	5·4814	·0268
79	22 5·5079	5·5343	5·5606	5·5869	5·6130	5·6391	5·6652	5·6911	5·7170	5·7428	·0261
80	5·7685	5·7941	5·8197	5·8452	5·8706	5·8959	5·9212	5·9463	5·9714	5·9665	·0253
81	6·0214	6·0463	6·0711	6·0959	6·1205	6·1451	6·1696	6·1941	6·2184	6·2427	·0245
82	22 6·2669	6·2910	6·3151	6·3390	6·3629	6·3867	6·4104	6·4340	6·4576	6·4810	·0237
83	6·5044	6·5277	6·5509	6·5740	6·5971	6·6201	6·6430	6·6658	6·6885	6·7111	·0229
84	6·7337	6·7562	6·7786	6·8009	6·8232	6·8454	6·8675	6·8895	6·9114	6·9333	·0221
85	22 6·9551	6·9768	6·9984	7·0200	7·0415	7·0629	7·0842	7·1055	7·1267	7·1478	·0214
86	7·1688	7·1898	7·2107	7·2315	7·2522	7·2729	7·2935	7·3140	7·3345	7·3549	·0206
87	7·3752	7·3954	7·4156	7·4357	7·4558	7·4757	7·4956	7·5155	7·5353	7·5550	·0199
88	22 7·5746	7·5942	7·6137	7·6332	7·6526	7·6719	7·6912	7·7104	7·7295	7·7486	·0193
89	7·7677	7·7866	7·8055	7·8244	7·8431	7·8618	7·8805	7·8991	7·9176	7·9360	·0187
90	7·9544	7·9727	7·9909	8·0091	8·0272	8·0452	8·0632	8·0812	8·0990	8·1168	·0180
91	22 8·1346	8·1523	8·1699	8·1875	8·2050	8·2225	8·2399	8·2573	8·2746	8·2918	·0174
92	8·3090	8·3261	8·3432	8·3602	8·3772	8·3941	8·4109	8·4277	8·4445	8·4611	·0169
93	8·4778	8·4943	8·5109	8·5273	8·5437	8·5601	8·5764	8·5927	8·6089	8·6250	·0163
94	22 8·6411	8·6572	8·6732	8·6892	8·7051	8·7209	8·7367	8·7525	8·7682	8·7838	·0158
95	8·7994	8·8150	8·8305	8·8459	8·8613	8·8767	8·8920	8·9073	8·9225	8·9376	·0153
96	8·9528	8·9678	8·9828	8·9978	9·0128	9·0276	9·0425	9·0573	9·0720	9·0867	·0149
97	22 9·1014	9·1160	9·1306	9·1451	9·1595	9·1740	9·1884	9·2027	9·2170	9·2312	·0144
98	9·2454	9·2596	9·2737	9·2878	9·3018	9·3158	9·3298	9·3437	9·3575	9·3713	·0140
99	9·3851	9·3989	9·4126	9·4262	9·4398	9·4534	9·4670	9·4805	9·4939	9·5073	·0136
100	22 9·5207	9·5340	9·5473	9·5606	9·5738	9·5869	9·6001	9·6132	9·6262	9·6392	·0132
101	9·6522	9·6651	9·6780	9·6908	9·7036	9·7164	9·7291	9·7418	9·7544	9·7670	·0127
102	9·7796	9·7921	9·8046	9·8170	9·8294	9·8417	9·8540	9·8662	9·8783	9·8904	·0123
103	22 9·9024	9·9144	9·9262	9·9380	9·9496	9·9612	9·9727	9·9841	9·9954	*0·0066	·0115
104	23 0·0177	0·0287	0·0396	0·0504	0·0610	0·0716	0·0820	0·0923	0·1025	0·1126	·0105
105	0·1226	0·1325	0·1423	0·1520	0·1615	0·1710	0·1804	0·1897	0·1988	0·2079	·0094
106	23 0·2170	0·2259	0·2347	0·2435	0·2522	0·2609	0·2694	0·2780	0·2864	0·2948	·0086
107	0·3031	0·3114	0·3196	0·3278	0·3359	0·3439	0·3520	0·3599	0·3678	0·3757	·0080
108	0·3835	0·3913	0·3990	0·4067	0·4143	0·4219	0·4295	0·4370	0·4445	0·4519	·0076
109	23 0·4593	0·4667	0·4740	0·4813	0·4885	0·4958	0·5030	0·5101	0·5172	0·5243	·0072
110	0·5314	0·5384	0·5454	0·5524	0·5593	0·5662	0·5731	0·5800	0·5868	0·5936	·0069
111	0·6004	0·6071	0·6139	0·6206	0·6272	0·6339	0·6405	0·6471	0·6537	0·6603	·0066
112	23 0·6668	0·6733	0·6798	0·6863	0·6928	0·6992	0·7056	0·7120	0·7184	0·7248	·0064
113	0·7311	0·7374	0·7437	0·7500	0·7563	0·7625	0·7688	0·7750	0·7812	0·7874	·0062
114	0·7936	0·7997	0·8059	0·8120	0·8181	0·8242	0·8303	0·8364	0·8424	0·8484	·0061
115	23 0·8545	0·8605	0·8665	0·8726	0·8787	0·8847	0·8906	0·8965	0·9024	0·9083	·0059
116	0·9142	0·9200	0·9259	0·9317	0·9375	0·9433	0·0490	0·9548	0·9605	0·9663	·0058
117	0·9720	0·9777	0·9833	0·9890	0·9947	1·0003	1·0059	1·0115	1·0171	1·0227	·0056
118	23 1·0283	1·0338	1·0394	1·0449	1·0504	1·0559	1·0614	1·0669	1·0723	1·0778	·0055
119	1·0832	1·0886	1·0940	1·0994	1·1048	1·1101	1·1154	1·1208	1·1261	1·1314	·0054
120	1·1367	1·1420	1·1473	1·1525	1·1578	1·1630	1·1682	1·1734	1·1786	1·1838	·0052
121	23 1·1889	1·1941	1·1992	1·2043	1·2095	1·2146	1·2196	1·2247	1·2298	1·2348	·0051
122	1·2399	1·2449	1·2499	1·2549	1·2599	1·2649	1·2698	1·2748	1·2797	1·2847	·0050
123	1·2896	1·2945	1·2994	1·3043	1·3091	1·3140	1·3188	1·3237	1·3285	1·3333	·0049
124	23 1·3381	1·3429	1·3477	1·3524	1·3572	1·3619	1·3667	1·3714	1·3761	1·3808	·0047
125	1·3855	1·3902	1·3948	1·3995	1·4041	1·4088	1·4134	1·4180	1·4226	1·4272	·0046
126	1·4318	1·4364	1·4410	1·4455	1·4501	1·4546	1·4591	1·4636	1·4681	1·4726	·0045
127	23 1·4771	1·4816	1·4860	1·4905	1·4949	1·4993	1·5038	1·5082	1·5126	1·5170	·0044
128	1·5214	1·5257	1·5301	1·5345	1·5388	1·5431	1·5475	1·5518	1·5561	1·5604	·0043
129	1·5647	1·5690	1·5732	1·5775	1·5818	1·5860	1·5902	1·5945	1·5987	1·6029	·0042

CHAP. IV.

Table of Values of $\frac{d^2}{w}t$ for Ogival-headed Shot.

v.	0	1	2	3	4	5	6	7	8	9	Diff.
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	+
130	23 1·6071	1·6113	1·6155	1·6196	1·6238	1·6280	1·6321	1·6362	1·6404	1·6445	·0042
131	1·6486	1·6527	1·6568	1·6609	1·6650	1·6690	1·6731	1·6772	1·6812	1·6852	·0041
132	1·6893	1·6933	1·6973	1·7013	1·7053	1·7093	1·7133	1·7173	1·7212	1·7252	·0040
133	23 1·7291	1·7331	1·7370	1·7410	1·7449	1·7488	1·7527	1·7566	1·7605	1·7644	·0039
134	1·7682	1·7721	1·7760	1·7798	1·7837	1·7875	1·7913	1·7952	1·7990	1·8028	·0038
135	1·8066	1·8104	1·8142	1·8179	1·8217	1·8255	1·8292	1·8330	1·8367	1·8405	·0038
136	23 1·8442	1·8479	1·8517	1·8554	1·8591	1·8628	1·8665	1·8702	1·8738	1·8775	·0037
137	1·8812	1·8848	1·8885	1·8921	1·8958	1·8994	1·9030	1·9067	1·9103	1·9139	·0036
138	1·9175	1·9211	1·9247	1·9282	1·9318	1·9354	1·9390	1·9425	1·9461	1·9496	·0036
139	23 1·9532	1·9567	1·9602	1·9638	1·9673	1·9708	1·9743	1·9778	1·9813	1·9848	·0035
140	1·9883	1·9918	1·9952	1·9987	2·0022	2·0056	2·0091	2·0125	2·0160	2·0194	·0035
141	2·0228	2·0263	2·0297	2·0331	2·0365	2·0399	2·0433	2·0467	2·0501	2·0535	·0034
142	23 2·0569	2·0602	2·0636	2·0670	2·0703	2·0737	2·0770	2·0804	2·0837	2·0870	·0034
143	2·0904	2·0937	2·0970	2·1003	2·1036	2·1069	2·1102	2·1135	2·1168	2·1201	·0033
144	2·1234	2·1267	2·1299	2·1332	2·1364	2·1397	2·1430	2·1462	2·1494	2·1527	·0033
145	23 2·1559	2·1591	2·1624	2·1656	2·1688	2·1720	2·1752	2·1784	2·1816	2·1848	·0032
146	2·1880	2·1912	2·1944	2·1975	2·2007	2·2039	2·2071	2·2102	2·2134	2·2165	·0032
147	2·2197	2·2228	2·2260	2·2291	2·2322	2·2354	2·2385	2·2416	2·2447	2·2478	·0031
148	23 2·2509	2·2540	2·2571	2·2602	2·2633	2·2664	2·2695	2·2726	2·2757	2·2787	·0031
149	2·2818	2·2849	2·2879	2·2910	2·2940	2·2971	2·3001	2·3032	2·3062	2·3093	·0030
150	2·3123	2·3153	2·3183	2·3214	2·3244	2·3274	2·3304	2·3334	2·3364	2·3394	·0030
151	23 2·3424	2·3454	2·3484	2·3514	2·3543	2·3573	2·3603	2·3633	2·3662	2·3692	·0030
152	2·3722	2·3751	2·3781	2·3810	2·3840	2·3869	2·3899	2·3928	2·3958	2·3987	·0029
153	2·4016	2·4046	2·4075	2·4104	2·4133	2·4162	2·4192	2·4221	2·4250	2·4279	·0029
154	23 2·4308	2·4337	2·4366	2·4395	2·4424	2·4453	2·4481	2·4510	2·4539	2·4568	·0029
155	2·4527	2·4625	2·4654	2·4683	2·4711	2·4740	2·4768	2·4797	2·4825	2·4854	·0029
156	2·4882	2·4911	2·4939	2·4967	2·4996	2·5024	2·5052	2·5080	2·5108	2·5137	·0028
157	23 2·5165	2·5193	2·5221	2·5249	2·5277	2·5305	2·5333	2·5361	2·5389	2·5416	·0028
158	2·5444	2·5472	2·5500	2·5528	2·5555	2·5583	2·5611	2·5638	2·5666	2·5693	·0028
159	2·5721	2·5748	2·5776	2·5803	2·5831	2·5858	2·5885	2·5913	2·5940	2·5967	·0027
160	23 2·5994	2·6022	2·6049	2·6076	2·6103	2·6130	2·6157	2·6184	2.6211	2·6238	·0027
161	2·6255	2·6292	2·6319	2·6346	2·6373	2·6400	2·6426	2·6453	2·6480	2·6506	·0027
162	2·6533	2·6560	2·6586	2·6613	2·6640	2·6666	2·6693	2·6719	2·6745	2·6772	·0026
163	23 2·6798	2·6825	2·6851	2·6877	2·6903	2·6930	2·6956	2·6982	2·7008	2·7034	·0026
164	2·7061	2·7087	2·7113	2·7139	2·7165	2.7191	2·7217	2·7243	2·7268	2·7294	·0026
165	2·7320	2·7346	2·7372	2·7398	2·7423	2·7449	2·7475	2·7500	2·7526	2·7552	·0026
166	23 2·7577	2·7603	2·7628	2·7654	2·7679	2·7705	2·7730	2·7756	2·7781	2·7806	·0025
167	2·7832	2·7857	2·7882	2·7908	2·7933	2·7958	2·7983	2·8008	2·8034	2·8059	·0025
168	2·8084	2·8109	2·8134	2·8159	2·8184	2·8209	2·8234	2·8258	2·8283	2·8308	·0025
169	23 2·8333	2·8358	2·8383	2·8407	2·8432	2·8457	2·8481	2·8506	2·8531	2·8555	·0025
170	2·8580	2·8604	2·8629	2·8653	2·8678	2·8702	2·8726	2·8751	2·8775	2·8799	·0024
171	2·8824	2·8848	2·8872	2·8896	2·8921	2·8945	2·8969	2·8993	2·9017	2·9041	·0024
172	23 2·9065	2·9089	2·9113	2·9137	2·9161	2·9185	2·9209	2·9233	2·9257	2·9281	·0024
173	2·9304	2·9328	2·9352	2·9376	2·9399	2·9423	2·9447	2·9470	2·9494	2·9518	·0024
174	2·9541	2·9565	2·9588	2·9612	2·9635	2·9659	2·9682	2·9705	2·9729	2·9752	·0023
175	23 2·9776	2·9799	2·9822	2·9845	2·9869	2·9892	2·9915	2·9938	2·9961	2·9985	·0023
176	3·0008	3·0031	3·0054	3·0077	3·0100	3·0123	3·0146	3·0169	3·0192	3·0215	·0023
177	3·0237	3·0260	3·0283	3·0306	3·0329	3·0351	3·0374	3·0397	3·0420	3·0442	·0023
178	23 3·0465	3·0488	3·0510	3·0533	3·0555	3·0578	3·0600	3·0623	3·0645	3·0668	·0023
179	3·0690	3·0713	3·0735	3·0757	3·0780	3·0802	3·0824	3·0847	3·0869	3·0891	·0022
180	3·0913	3·0935	3·0958	3·0980	3·1002	3·1024	3·1045	3·1068	3·1090	3·1112	·0022
181	23 3·1134	3·1156	3·1178	3·1200	3·1222	3·1244	3·1266	3·1287	3·1309	3·1331	·0022
182	3·1353	3·1375	3·1396	3·1418	3·1440	3·1461	3·1483	3·1505	3·1526	3·1548	·0022
183	3·1569	3·1591	3·1613	3·1634	3·1656	3·1677	3·1698	3·1720	3·1741	3·1763	·0021
184	23 3·1784	3·1806	3·1827	3·1848	3·1869	3·1891	3·1912	3·1933	3·1954	3·1975	·0021
185	3·1997	3·2018	3·2039	3·2060	3·2081	3·2102	3·2123	3·2144	3·2165	3·2186	·0021
186	3·2207	3·2228	3·2249	3·2270	3·2291	3·2312	3·2333	3·2353	3·2374	3·2395	·0021
187	23 3·2416	3·2437	3·2457	3·2478	3·2499	3·2520	3·2540	3·2561	3·2582	3·2602	·0021
188	3·2623	3·2643	3·2664	3·2685	3·2706	3·2726	3·2746	3·2767	3·2787	3·2808	·0021
189	3·2828	3·2848	3·2869	3·2889	3·2909	3·2930	3·2950	3·2970	3·2991	3·3011	·0020

Table of Values of $\frac{d^2}{w}t$ for Ogival-headed Shot.

V.	0	1	2	3	4	5	6	7	8	9	Diff.
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	+
190	23 3·3031	3·3051	3·3072	3·3092	3·3112	3·3132	3·3152	3·3172	3·3192	3·3212	·0030
191	3·3234	3·3253	3·3273	3·3293	3·3313	3·3333	3·3353	3·3372	3·3392	3·3412	·0020
192	3·3433	3·3452	3·3472	3·3492	3·3511	3·3531	3·3551	3·3571	3·3590	3·3610	·0020
193	23 3·3630	3·3649	3·3669	3·3689	3·3708	3·3728	3·3747	3·3767	3·3786	3·3806	·0020
194	3·3825	3·3845	3·3864	3·3884	3·3903	3·3922	3·3942	3·3961	3·3980	3·4000	·0019
195	3·4019	3·4038	3·4057	3·4077	3·4096	3·4115	3·4134	3·4153	3·4172	3·4192	·0019
196	23 3·4211	3·4230	3·4249	3·4268	3·4287	3·4306	3·4325	3·4344	3·4362	3·4381	·0019
197	3·4400	3·4419	3·4438	3·4457	3·4476	3·4494	3·4513	3·4532	3·4550	3·4569	·0019
198	3·4588	3·4606	3·4625	3·4644	3·4662	3·4681	3·4699	3·4718	3·4736	3·4755	·0019
199	23 3·4773	3·4791	3·4810	3·4828	3·4846	3·4865	3·4883	3·4901	3·4920	3·4938	·0018
200	3·4956	3·4974	3·4992	3·5010	3·5028	3·5047	3·5065	3·5083	3·5101	3·5119	·0018
201	3·5137	3·5155	3·5172	3·5190	3·5208	3·5226	3·5244	3·5262	3·5280	3·5297	·0018
202	23 3·5315	3·5333	3·5351	3·5368	3·5386	3·5404	3·5421	3·5439	3·5456	3·5474	·0018
203	3·5492	3·5509	3·5527	3·5544	3·5561	3·5579	3·5596	3·5614	3·5631	3·5648	·0017
204	3·5666	3·5683	3·5700	3·5717	3·5735	3·5752	3·5769	3·5786	3·5803	3·5820	·0017
205	23 3·5837	3·5854	3·5871	3·5888	3·5905	3·5922	3·5939	3·5956	3·5973	3·5990	·0017
206	3·6007	3·6024	3·6040	3·6057	3·6074	3·6091	3·6107	3·6124	3·6141	3·6157	·0017
207	3·6174	3·6191	3·6207	3·6224	3·6240	3·6257	3·6273	3·6290	3·6306	3·6323	·0016
208	23 3·6339	3·6355	3·6372	3·6388	3·6404	3·6420	3·6437	3·6453	3·6469	3·6485	·0016
209	3·6502	3·6518	3·6534	3·6550	3·6566	3·6582	3·6598	3·6614	3·6630	3·6646	·0016
210	3·6662	3·6678	3·6694	3·6710	3·6726	3·6741	3·6757	3·6773	3·6789	3·6805	·0016
211	23 3·6820	3·6836	3·6852	3·6867	3·6883	3·6899	3·6914	3·6930	3·6946	3·6961	·0016
212	3·6977	3·6992	3·7008	3·7023	3·7039	3·7054	3·7070	3·7085	3·7100	3·7116	·0015
213	3·7131	3·7146	3·7162	3·7177	3·7192	3·7207	3·7223	3·7238	3·7253	3·7268	·0015
214	23 3·7283	3·7298	3·7313	3·7329	3·7344	3·7359	3·7374	3·7389	3·7404	3·7419	·0015
215	3·7434	3·7448	3·7463	3·7478	3·7493	3·7508	3·7523	3·7538	3·7552	3·7567	·0015
216	3·7582	3·7597	3·7612	3·7626	3·7641	3·7656	3·7670	3·7685	3·7700	3·7714	·0015
217	23 3·7729	3·7743	3·7758	3·7772	3·7787	3·7801	3·7816	3·7830	3·7845	3·7859	·0014
218	3·7874	3·7888	3·7902	3·7917	3·7931	3·7945	3·7960	3·7974	3·7988	3·8002	·0014
219	3·8016	3·8031	3·8045	3·8059	3·8073	3·8087	3·8101	3·8115	3·8129	3·8144	·0014
220	23 3·8158	3·8172	3·8186	3·8200	3·8214	3·8227	3·8241	3·8255	3·8269	3·8283	·0014
221	3·8297	3·8311	3·8325	3·8338	3·8352	3·8366	3·8380	3·8394	3·8407	3·8421	·0014
222	3·8435	3·8448	3·8462	3·8476	3·8489	3·8503	3·8517	3·8530	3·8544	3·8557	·0014
223	23 3·8571	3·8584	3·8598	3·8611	3·8625	3·8638	3·8651	3·8665	3·8678	3·8692	·0013
224	3·8705	3·8718	3·8732	3·8745	3·8758	3·8772	3·8785	3·8798	3·8811	3·8824	·0013
225	3·8838	3·8851	3·8864	3·8877	3·8890	3·8903	3·8916	3·8930	3·8943	3·8956	·0013
226	23 3·8969	3·8982	3·8995	3·9008	3·9021	3·9034	3·9047	3·9059	3·9072	3·9085	·0013
227	3·9098	3·9111	3·9124	3·9137	3·9150	3·9162	3·9175	3·9188	3·9201	3·9214	·0013
228	3·9226	3·9239	3·9252	3·9264	3·9277	3·9290	3·9303	3·9315	3·9328	3·9341	·0013
229	23 3·9353	3·9366	3·9378	3·9391	3·9404	3·9416	3·9429	3·9441	3·9454	3·9467	·0013
230	3·9479	3·9492	3·9504	3·9517	3·9529	3·9542	3·9554	3·9567	3·9579	3·9592	·0013
231	3·9604	3·9617	3·9629	3·9642	3·9654	3·9667	3·9679	3·9692	3·9704	3·9716	·0012
232	23 3·9729	3·9741	3·9754	3·9766	3·9779	3·9791	3·9803	3·9816	3·9828	3·9841	·0012
233	3·9853	3·9866	3·9878	3·9890	3·9903	3·9915	3·9927	3·9940	3·9952	3·9965	·0012
234	3·9977	3·9989	4·0002	4·0014	4·0026	4·0039	4·0051	4·0063	4·0076	4·0088	·0012
235	23 4·0100	4·0113	4·0125	4·0137	4·0150	4·0162	4·0174	4·0186	4·0199	4·0211	·0012
236	4·0223	4·0236	4·0248	4·0260	4·0272	4·0284	4·0297	4·0309	4·0321	4·0334	·0012
237	4·0346	4·0358	4·0370	4·0383	4·0395	4·0407	4·0419	4·0431	4·0444	4·0456	·0012
238	23 4·0468	4·0480	4·0492	4·0505	4·0517	4·0529	4·0541	4·0553	4·0566	4·0578	·0012
239	4·0590	4·0602	4·0614	4·0626	4·0639	4·0651	4·0663	4·0675	4·0687	4·0699	·0012
240	4·0711	4·0724	4·0736	4·0748	4·0760	4·0772	4·0784	4·0796	4·0809	4·0821	·0012
241	23 4·0833	4·0845	4·0857	4·0869	4·0881	4·0893	4·0905	4·0917	4·0930	4·0942	·0012
242	4·0954	4·0966	4·0978	4·0990	4·1002	4·1014	4·1026	4·1038	4·1050	4·1062	·0012
243	4·1074	4·1087	4·1099	4·1111	4·1123	4·1135	4·1147	4·1159	4·1171	4·1183	·0012
244	23 4·1195	4·1207	4·1219	4·1231	4·1243	4·1255	4·1267	4·1279	4·1291	4·1303	·0012
245	4·1315	4·1327	4·1339	4·1351	4·1363	4·1375	4·1387	4·1399	4·1411	4·1423	·0012
246	4·1435	4·1447	4·1459	4·1471	4·1483	4·1495	4·1506	4·1518	4·1530	4·1542	·0012
247	23 4·1554	4·1566	4·1578	4·1590	4·1602	4·1614	4·1626	4·1638	4·1649	4·1661	·0012
248	4·1673	4·1685	4·1697	4·1709	4·1721	4·1733	4·1744	4·1756	4·1768	4·1780	·0021
249	4·1792	4·1804	4·1815	4·1827	4·1839	4·1851	4·1863	4·1874	4·1886	4·1898	·0012

CHAP. IV.

Table of Values of $\frac{d^2}{w}t$ for Ogival-headed Shot.

v.	0	1	2	3	4	5	6	7	8	9	Diff.
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	+
250	23 4·1910	4·1922	4·1933	4·1945	4·1957	4·1969	4·1980	4·1992	4·2004	4·2015	·0012
251	4·2027	4·2039	4·2051	4·2062	4·2074	4·2086	4·2097	4·2109	4·2121	4·2132	·0012
252	4·2144	4·2156	4·2167	4·2179	4·2190	4·2202	4·2214	4·2225	4·2237	4·2248	·0012
253	23 4·2260	4·2272	4·2283	4·2295	4·2306	4·2318	4·2329	4·2341	4·2352	4·2364	·0012
254	4·2375	4·2387	4·2398	4·2410	4·2421	4·2433	4·2444	4·2455	4·2467	4·2478	·0011
255	4·2490	4·2501	4·2513	4·2524	4·2535	4·2547	4·2558	4·2569	4·2581	4·2592	·0011
256	23 4·2603	4·2615	4·2626	4·2637	4·2648	4·2660	4·2671	4·2682	4·2693	4·2705	·0011
257	4·2716	4·2727	4·2738	4·2749	4·2760	4·2772	4·2783	4·2794	4·2805	4·2816	·0011
258	4·2827	4·2838	4·2849	4·2860	4·2871	4·2882	4·2893	4·2904	4·2915	4·2926	·0011
259	23 4·2937	4·2948	4·2959	4·2970	4·2981	4·2992	4·3003	4·3014	4·3025	4·3036	·0011
260	4·3046	4·3057	4·3068	4·3079	4·3090	4·3101	4·3111	4·3122	4·3133	4·3144	·0011
261	4·3154	4·3165	4·3176	4·3187	4·3197	4·3208	4·3219	4·3229	4·3240	4·3250	·0011
262	23 4·3261	4·3272	4·3282	4·3293	4·3303	4·3314	4·3325	4·3335	4·3346	4·3356	·0011
263	4·3367	4·3377	4·3388	4·3398	4·3409	4·3419	4·3429	4·3440	4·3450	4·3461	·0010
264	4·3471	4·3482	4·3492	4·3502	4·3513	4·3523	4·3533	4·3544	4·3554	4·3564	·0010
265	23 4·3574	4·3585	4·3595	4·3605	4·3615	4·3626	4·3636	4·3646	4·3656	4·3667	·0010
266	4·3677	4·3687	4·3697	4·3707	4·3717	4·3728	4·3738	4·3748	4·3758	4·3768	·0010
267	4·3778	4·3788	4·3798	4·3808	4·3818	4·3828	4·3838	4·3848	4·3858	4·3868	·0010
268	23 4·3878	4·3888	4·3898	4·3908	4·3918	4·3928	4·3938	4·3948	4·3958	4·3968	·0010
269	4·3977	4·3987	4·3997	4·4007	4·4017	4·4027	4·4036	4·4046	4·4056	4·4066	·0010
270	4·4075	4·4085	4·4095	4·4105	4·4114	4·4124	4·4134	4·4143	4·4153	4·4163	·0010
271	23 4·4172	4·4182	4·4192	4·4201	4·4211	4·4220	4·4230	4·4240	4·4249	4·4259	·0010
272	4·4268	4·4278	4·4287	4·4297	4·4307	4·4316	4·4326	4·4335	4·4344	4·4354	·0010
273	4·4363	4·4373	4·4382	4·4392	4·4401	4·4411	4·4420	4·4429	4·4439	4·4448	·0009
274	23 4·4457	4·4467	4·4476	4·4485	4·4495	4·4504	4·4513	4·4523	4·4532	4·4541	·0009
275	4·4551	4·4560	4·4569	4·4587	4·4587	4·4597	4·4606	4·4615	4·4624	4·4633	·0009
276	4·4643	4·4652	4·4661	4·4670	4·4679	4·4688	4·4697	4·4706	4·4715	4·4725	·0009
277	23 4·4734	4·4743	4·4752	4·4761	4·4770	4·4779	4·4788	4·4797	4·4806	4·4815	·0009
278	4·4824	4·4833	4·4842	4·4850	4·4859	4·4868	4·4877	4·4886	4·4895	4·4904	·0009
279	4·4913	4·4922	4·4930	4·4939	4·4948	4·4957	4·4966	4·4975	4·4983	4·4992	·0009
280	23 4·5001	4·5010	4·5018	4·5027	4·5036	4·5045	4·5053	4·5062	4·5071	4·5080	·0009
281	4·5088	4·5097	4·5105	4·5114	4·5123	4·5131	4·5140	4·5148	4·5157	4·5166	·0009
282	4·5174	4·5183	4·5191	4·5200	4·5208	4·5217	4·5226	4·5234	4·5243	4·5251	·0009
283	23 4·5260	4·5268	4·5277	4·5285	4·5293	4·5302	4·5310	4·5319	4·5327	4·5336	·0008
284	4·5344	4·5352	4·5361	4·5369	4·5378	4·5386	4·5394	4·5403	4·5411	4·5419	·0008
285	4·5427	4·5436	4·5444	4·5452	4·5461	4·5469	4·5477	4·5485	4·5494	4·5502	·0008
286	23 4·5510	4·5518	4·5527	4·5535	4·5543	4·5551	4·5559	4·5567	4·5576	4·5584	·0008
287	4·5592	4·5600	4·5608	4·5616	4·5624	4·5632	4·5641	4·5648	4·5657	4·5665	·0008
288	4·5673	4·5681	4·5689	4·5697	4·5705	4·5713	4·5721	4·5729	4·5737	4·5745	·0008
289	23 4·5753	4·5761	4·5769	4·5777	4·5785	4·5793	4·5800	4·5808	4·5816	4·5824	·0008
290	4·5832										

TABLE VII.

Table of Values of $\frac{d^2}{w}s$ for Ogival-headed Shot.

v.	0	1	2	3	4	5	6	7	8	9	Diff.
f.s.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	+
10	1066	1238	1409	1578	1745	1910	2074	2236	2397	2557	166
11	2715	2871	3026	3180	3333	3484	3638	3782	3929	4075	151
12	4220	4363	4506	4647	4787	4926	5064	5200	5336	5471	139
13	5604	5737	5866	5999	6129	6257	6385	6511	6637	6762	129
14	6886	7009	7132	7253	7373	7493	7612	7730	7847	7964	120
15	8079	8194	8309	8422	8535	8647	8758	8868	8978	9087	112
16	9196	9304	9411	9517	9623	9728	9833	9937	10040	10142	105
17	10244	10346	10447	10546	10615	10743	10841	10939	11037	11134	98
18	11230	11326	11421	11516	11610	11704	11797	11890	11982	12074	94
19	12165	12256	12346	12436	12525	12614	12703	12791	12878	12966	89
20	13052	13139	13224	13310	13395	13480	13564	13648	13731	13814	85
21	13896	13979	14060	14142	14223	14303	14384	14463	14543	14622	81
22	14701	14779	14857	14935	15013	15090	15167	15244	15319	15395	77
23	15470	15545	15620	15694	15768	15842	15916	15989	16061	16134	74
24	16206	16278	16350	16421	16492	16563	16633	16703	16773	16843	71
25	1 6912·1	6981·2	7050·0	7118·5	7186·7	7254·7	7322·4	7389·8	7457·0	7523·9	68·0
26	7590·6	7657·0	7723·2	7789·1	7854·7	7920·1	7985·3	8050·2	8114·8	8179·3	65·4
27	8243·5	8307·5	8371·2	8434·7	8498·0	8561·0	8623·9	8686·4	8748·8	8810·9	63·0
28	1 8872·8	8934·5	8996·0	9057·2	9118·3	9179·1	9239·7	9300·1	9360·3	9420·3	60·8
29	9480·0	9539·6	9598·9	9658·1	9717·0	9775·8	9834·3	9892·6	9950·8	*0008·7	58·7
30	2 0066·5	0124·0	0181·4	0238·5	0295·5	0352·3	0409·0	0465·4	0521·7	0577·7	56·8
31	2 0633·6	0689·3	0744·8	0800·1	0855·3	0910·2	0965·0	1019·6	1074·0	1128·3	55·0
32	1182·4	1236·3	1290·0	1343·5	1396·9	1450·2	1503·2	1556·1	1608·8	1661·4	53·2
33	1713·8	1766·0	1818·1	1870·0	1921·7	1973·3	2024·7	2076·0	2127·1	2178·1	51·6
34	2 2228·9	2279·6	2330·0	2380·4	2430·6	2490·6	2530·5	2580·2	2629·7	2679·1	50·0
35	2728·4	2777·5	2826·4	2875·2	2923·8	2972·3	3020·7	3068·8	3116·9	3164·7	48·5
36	3212·5	3260·1	3307·5	3354·8	3402·0	3449·0	3495·9	3542·6	3589·2	3635·6	47·0
37	2 3682·0	3728·1	3774·2	3820·0	3865·8	3911·4	3956·9	4002·2	4047·4	4092·5	45·6
38	4137·4	4182·2	4226·8	4271·4	4315·7	4360·0	4404·1	4448·1	4491·9	4535·7	44·3
39	4579·2	4622·7	4666·0	4709·2	4752·3	4795·2	4838·1	4880·8	4923·3	4965·7	42·9
40	2 5008·0	5050·2	5092·3	5134·2	5176·0	5217·6	5259·2	5300·6	5341·9	5383·0	41·7
41	5424·0	5464·9	5505·7	5546·4	5586·9	5627·3	5667·6	5707·8	5747·8	5787·8	40·4
42	5827·6	5867·3	5906·9	5946·4	5985·8	6025·0	6064·2	6103·3	6142·2	6181·0	39·3
43	2 6219·8	6258·4	6296·9	6335·3	6373·6	6411·8	6449·9	6487·9	6525·8	6563·6	38·2
44	6601·3	6638·9	6676·4	6713·7	6751·0	6788·2	6825·3	6862·3	6899·3	6936·1	37·2
45	6972·8	7009·4	7046·0	7082·4	7118·8	7155·0	7191·2	7227·8	7263·3	7299·2	36·3
46	2 7335·1	7370·8	7406·5	7442·1	7477·6	7513·0	7548·3	7583·6	7618·8	7653·9	35·4
47	7688·9	7723·8	7758·7	7793·5	7828·2	7862·8	7897·3	7931·8	7966·2	8000·5	34·6
48	8034·7	8068·9	8103·0	8137·0	8170·9	8204·8	8238·3	8272·3	8305·9	8339·5	33·9
49	2 8373·0	8406·5	8439·8	8473·1	8506·4	8539·5	8572·6	8605·6	8638·6	8671·5	33·2
50	8704·3	8737·1	8769·8	8802·4	8835·0	8867·5	8900·0	8932·3	8964·7	8996·9	32·5
51	9029·1	9061·2	9093·2	9125·2	9157·1	9189·0	9220·8	9252·5	9284·2	9315·8	31·9
52	2 9347·3	9378·8	9410·3	9441·6	9472·9	9504·2	9535·4	9566·5	9597·6	9628·7	31·3
53	9659·6	9690·6	9721·4	9752·2	9783·0	9813·7	9844·3	9874·9	9905·4	9935·9	30·7
54	9966·3	9996·7	*0027·0	*0057·3	*0087·5	*0117·7	*0147·8	*0177·8	*0207·8	*0237·8	30·2
55	2 3027·6	0297·5	0327·3	0357·0	0386·7	0416·3	0445·9	0475·4	0504·9	0534·3	29·8
56	0563·6	0592·9	0622·2	0651·4	0680·6	0709·7	0738·7	0767·7	0796·7	0825·6	29·1
57	0854·5	0883·3	0912·1	0940·9	0969·6	0998·2	1026·8	1055·4	1083·9	1112·4	28·6
58	3 1140·8	1169·2	1197·6	1226·0	1254·3	1282·5	1310·8	1339·0	1367·1	1395·2	28·3
59	1423·3	1451·3	1479·3	1507·3	1535·2	1563·0	1590·9	1618·7	1646·4	1674·2	27·9
60	1701·8	1729·5	1757·1	1784·6	1812·2	1839·6	1867·1	1894·5	1921·9	1949·2	27·5
61	3 1976·5	2003·7	2031·0	2058·1	2085·3	2112·4	2139·4	2166·4	2193·4	2220·4	27·1
62	2247·3	2274·2	2301·0	2327·8	2354·5	2381·3	2407·9	2434·6	2461·2	2487·7	26·7
63	2514·3	2540·8	2567·2	2593·6	2620·0	2646·3	2672·6	2698·9	2725·1	2751·3	26·3
64	3 2777·5	2803·6	2829·7	2855·7	2881·7	2907·7	2933·7	2959·6	2985·4	3011·2	26·0
65	3037·0	3062·8	3088·5	3114·2	3139·8	3165·4	3191·0	3216·5	3242·0	3267·4	25·6
66	3292·8	3318·2	3343·5	3368·8	3394·1	3419·3	3444·5	3469·6	3494·7	3519·8	25·2
67	3 3544·8	3569·8	3594·8	3619·8	3644·7	3669·5	3694·3	3719·1	3743·9	3768·6	24·8
68	3793·3	3818·0	3842·6	3867·2	3891·7	3916·2	3940·7	3965·2	3989·6	4014·0	24·5
69	4038·4	4062·7	4087·0	4111·3	4135·6	4159·8	4184·0	4208·1	4232·2	4256·3	24·2

CHAP. IV

Table of Values of $\frac{d^2}{w}s$ for Ogival-headed Shot.

v	0	1	2	3	4	5	6	7	8	9	Diff.
f.s.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	+
70	3 4280·4	4304·5	4328·5	4352·4	4376·4	4400·3	4424·1	4448·0	4471·8	4495·5	23·9
71	4519·3	4543·0	4566·6	4590·2	4613·8	4637·4	4660·9	4684·4	4707·8	4731·3	23·5
72	4754·7	4777·9	4801·3	4824·6	4847·9	4871·1	4891·2	4917·4	4940·5	4963·6	23·2
73	3 4986·6	5009·6	5032·6	5055·5	5078·4	5101·3	5124·1	5146·9	5169·6	5192·4	22·8
74	5215·1	5237·7	5260·3	5282·9	5305·5	5328·0	5350·5	5373·0	5395·4	5417·8	22·5
75	5440·2	5462·5	5484·8	5507·1	5529·3	5551·5	5573·7	5595·8	5617·9	5640·0	22·2
76	3 5662·1	5684·1	5706·0	5728·0	5749·9	5771·7	5793·5	5815·3	5837·0	5858·7	21·8
77	5880·4	5902·0	5923·6	5945·1	5966·6	5988·1	6009·5	6030·9	6052·2	6073·6	21·5
78	6094·8	6116·1	6137·3	6158·4	6179·6	6200·7	6221·7	6242·7	6263·7	6284·6	21·1
79	3 6305·5	6326·4	6347·2	6368·0	6388·8	6409·5	6430·2	6150·8	6471·4	6492·0	20·7
80	6512·6	6533·1	6553·6	6574·0	6594·4	6614·8	6635·1	6655·4	6675·7	6695·9	20·4
81	6716·1	6736·3	6756·4	6776·5	6796·5	9816·5	6836·5	6856·4	6876·3	6896·1	20·0
82	3 6916·0	6935·7	6955·5	6975·1	6994·8	7014·4	7033·9	7053·4	7072·9	7092·3	19·6
83	7111·7	7131·0	7150·3	7169·6	7188·8	7207·9	7227·1	7246·1	7265·2	7284·1	19·1
84	7303·1	7322·0	7340·8	7359·6	7378·4	7397·1	7415·8	7434·4	7453·0	7471·5	18·7
85	3 7490·0	7508·5	7526·9	7545·3	7563·6	7581·8	7600·0	7618·2	7636·3	7654·4	18·2
86	7672·4	7690·5	7708·4	7726·4	7744·2	7762·0	7779·9	7797·6	7815·4	7833·0	17·8
87	7850·6	7868·2	7885·8	7903·3	7920·8	7938·2	7955·6	7973·0	7990·3	8007·6	17·4
88	3 8024·8	8042·0	8059·2	8076·3	8093·4	8110·4	8127·4	8144·4	8161·3	8178·2	17·0
89	8195·0	8211·9	8228·6	8245·4	8262·1	8278·7	8295·4	8312·0	8328·5	8345·0	16·6
90	8361·5	8377·9	8394·3	8410·7	8427·0	8443·3	8459·6	8475·8	8492·0	8508·2	16·3
91	3 8524·3	8540·4	8556·4	8572·4	8588·4	8604·3	8620·3	8636·1	8652·0	8667·8	15·9
92	8683·5	8699·3	8715·0	8730·7	8746·3	8761·9	8777·5	8793·0	8808·5	8824·0	15·6
93	8839·4	8854·8	8870·2	8885·5	8900·8	8916·1	8931·3	8946·5	8961·7	8976·8	15·3
94	3 8991·9	9007·0	9022·0	9037·0	9052·0	9066·9	9081·9	9096·7	9111·6	9126·4	15·0
95	9141·2	9156·0	9170·7	9185·4	9200·1	9214·7	9229·3	9243·9	9258·4	9272·9	14·6
96	9287·4	9301·9	9316·3	9330·7	9345·0	9359·4	9373·7	9387·9	9402·2	9416·4	14·3
97	3 9430·6	9144·7	9458·9	9473·0	9487·0	9501·1	9515·1	9529·1	9543·0	9557·0	14·0
98	9570·8	9584·7	9598·6	9612·4	9626·1	9639·9	9653·6	9667·3	9681·0	9694·6	13·7
99	9708·3	9721·9	9735·4	9749·0	9762·5	9775·9	9789·4	9802·8	9816·2	9829·6	13·5
100	3 9842·9	9856·3	9869·6	9852·9	9896·1	9909·3	9922·5	9935·8	9948·8	9961·9	13·2
101	9975·0	9988·1	*0001·1	*0014·1	*0027·1	*0040·0	*0052·9	*0065·8	*0078·7	*0091·5	12·9
102	4 0104·3	0117·1	0129·8	0142·5	0155·2	0167·8	0180·4	0192·9	0205·4	0217·8	12·6
103	4 0230·1	0242·4	0254·6	0266·8	0278·8	0290·8	0302·7	0314·5	0326·2	0337·8	11·9
104	0349·4	0360·8	0372·2	0383·4	0394·5	0405·6	0416·5	0427·3	0438·1	0448·7	11·0
105	0459·2	0469·6	0479·9	0490·0	0500·1	0510·1	0520·0	0529·8	0539·5	0549·2	9·9
106	4 0558·7	0568·2	0577·6	0586·9	0596·2	0605·4	0614·5	0623·6	0632·6	0641·6	9·2
107	0650·5	0659·3	0668·1	0676·9	0685·6	0694·2	0702·8	0711·4	0719·9	0728·4	8·6
108	0736·8	0745·2	0753·6	0761·9	0770·2	0778·4	0786·6	0794·8	0802·9	0811·0	8·2
109	4 0819·0	0827·1	0835·0	0843·0	0850·9	0858·9	0866·7	0874·6	0882·4	0890·2	7·9
110	0897·9	0905·7	0913·4	0921·1	0928·7	0936·4	0914·0	0951·5	0959·1	0966·6	7·6
111	0974·2	0981·6	0989·1	0996·6	1004·0	1011·4	1018·8	1026·2	1033·5	1040·9	7·4
112	4 1048·2	1055·5	1062·8	1070·0	1077·3	1084·5	1091·7	1099·0	1106·1	1113·3	7·2
113	1120·5	1127·6	1134·8	1141·9	1149·0	1156·1	1163·2	1170·2	1177·3	1184·4	7·1
114	1191·4	1198·4	1205·4	1212·4	1219·4	1226·4	1233·3	1240·3	1247·2	1254·1	6·9
115	4 1261·0	1267·9	1274·8	1281·7	1288·6	1295·4	1302·3	1309·1	1315·9	1322·7	6·8
116	1329·5	1336·3	1343·1	1349·8	1356·6	1363·3	1370·0	1376·7	1383·4	1390·1	6·7
117	1396·8	1403·5	1410·1	1416·8	1423·4	1430·0	1436·6	1443·2	1449·8	1456·4	6·6
118	4 1462·9	1469·5	1476·0	1482·6	1489·1	1495·6	1502·1	1508·6	1515·1	1521·5	6·5
119	1528·0	1534·4	1540·9	1547·3	1553·7	1560·1	1566·5	1572·9	1579·2	1585·6	6·4
120	1591·9	1598·3	1604·6	1610·9	1617·2	1623·5	1629·8	1636·1	1642·3	1648·6	6·3
121	4 1654·3	1661·1	1667·3	1673·5	1679·7	1685·9	1692·1	1698·2	1704·4	1710·5	6·2
122	1716·7	1722·8	1728·9	1735·0	1741·1	1747·2	1753·3	1759·4	1765·4	1771·5	6·1
123	1777·5	1783·6	1789·6	1795·6	1801·6	1807·6	1813·6	1819·6	1825·6	1831·5	6·0
124	4 1837·5	1843·4	1849·4	1855·3	1861·2	1867·1	1873·0	1878·9	1884·8	1890·6	5·9
125	1896·5	1902·3	1908·2	1914·0	1919·8	1925·6	1931·5	1937·3	1943·0	1948·8	5·8
126	1954·6	1960·4	1966·1	1971·9	1977·6	1983·3	1989·0	1994·8	2000·5	2006·2	5·7
127	4 2011·8	2017·5	2023·2	2028·9	2034·5	2040·2	2045·8	2051·4	2057·0	2062·7	5·6
128	2068·3	2073·9	2079·5	2085·0	2090·6	2096·2	2101·8	2107·3	2112·9	2118·4	5·6
129	2123·9	2129·4	2185·0	2140·5	2146·0	2151·5	2157·0	2162·4	2167·9	2173·4	5·5

CHAP. IV.

Table of Values of $\frac{d^2}{w}s$ for Ogival-headed Shot.

v.	0	1	2	3	4	6	6	7	8	9	Diff.
f.s.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	+
130	4 2178·8	2184·3	2189·7	2195·1	2200·6	2206·0	2211·4	2216·8	2222·2	2227·6	5·4
131	2233·0	2238·4	2243·7	2249·1	2254·5	2259·8	2265·1	2270·5	2275·8	2281·1	5·3
132	2286·4	2291·8	2297·1	2302·4	2307·6	2312·9	2318·2	2323·5	2328·7	2334·0	5·3
133	4 2339·2	2344·5	2349·7	2355·0	2360·2	2265·4	2370·6	2375·8	2381·0	2386·2	5·2
134	2391·4	2396·6	2401·8	2406·9	2412·1	2417·3	2422·4	2427·6	2432·7	2437·8	5·2
135	2443·0	2448·1	2453·2	2458·3	2463·4	2468·5	2473·6	2478·7	2483·8	2488·9	5·1
136	4 2493·9	2499·0	2504·1	2509·1	2514·2	2519·2	2524·3	2529·3	2534·3	2539·4	5·0
137	2544·4	2549·4	2554·4	2559·4	2564·4	2569·4	2574·4	2579·4	2584·3	2589·3	5·0
138	2594·3	2599·2	2604·2	2609·1	2614·1	2619·0	2624·0	2628·9	2633·8	2638·8	4·9
139	4 2643·7	2648·6	2653·5	2658·4	2663·3	2668·2	2673·1	2678·0	2682·9	2687·8	4·9
140	2692·6	2697·5	2702·4	2707·2	2712·1	2717·0	2721·8	2726·7	2731·5	2736·3	4·9
141	2741·2	2746·0	2750·8	2755·7	2760·5	2765·3	2770·1	2774·9	2779·7	2784·5	4·8
142	4 2789·3	2794·1	2798·9	2803·7	2808·5	2813·2	2818·0	2822·8	2827·5	2832·3	4·8
143	2837·1	2841·8	2846·6	2851·3	2856·0	2860·8	2865·5	2870·2	2875·0	2879·7	4·7
144	2884·4	2889·1	2893·8	2898·6	2903·3	2908·0	2912·7	2917·4	2922·1	2926·7	4·7
145	4 2931·4	2936·1	2940·8	2945·5	2950·1	2954·8	2959·5	2964·1	2968·8	2973·5	4·7
146	2978·1	2982·8	2987·4	2992·1	2996·7	3001·3	3006·0	3010·6	3015·2	3019·9	4·6
147	3024·5	3029·1	3033·7	3038·4	3043·0	3047·6	3052·2	3056·8	3061·4	3066·0	4·6
148	4 3070·6	3075·2	3079·8	3084·4	3089·0	3093·5	3098·1	3102·7	3107·3	3111·8	4·6
149	3116·4	3121·0	3125·6	3130·1	3134·7	3139·2	3143·8	3148·3	3152·9	3157·4	4·6
150	3162·0	3166·5	3171·0	3175·6	3180·1	3184·6	3189·2	3193·7	3198·2	3202·7	4·5
151	4 3207·2	3211·8	3216·3	3220·8	3225·3	3229·8	3234·3	3238·8	3243·3	3247·8	4·5
152	3252·3	3256·8	3261·3	3265·8	3270·3	3274·8	3279·3	3283·8	3288·3	3292·8	4·5
153	3297·2	3301·7	3306·2	3310·6	3315·1	3319·6	3324·1	3328·5	3333·0	3337·5	4·5
154	4 3342·0	3346·4	3350·9	3355·3	3359·8	3364·3	3368·7	3373·2	3377·6	3382·1	4·5
155	3386·5	3391·0	3395·4	3399·9	3404·3	3408·7	3413·2	3417·6	3422·0	3426·5	4·4
156	3430·9	3435·3	3439·8	3444·2	3448·6	3453·0	3457·4	3461·9	3466·3	3470·7	4·4
157	4 3475·1	3479·5	3483·9	3488·3	3492·7	3497·1	3501·5	3505·9	3510·3	3514·7	4·4
158	3519·1	3523·5	3527·9	3532·3	3536·7	3541·1	3545·4	3549·8	3554·2	3558·6	4·4
159	3563·0	3567·3	3571·7	3576·1	3580·4	3584·8	3589·1	3593·5	3597·9	3602·2	4·4
160	4 3606·6	3610·9	2615·3	3619·6	3624·0	3628·3	3632·6	3637·0	3641·3	3645·7	4·3
161	3650·0	3654·3	3658·7	3663·0	3667·3	3671·6	3676·0	3680·3	3684·6	3688·9	4·3
162	3693·3	3697·6	3701·9	3706·1	3710·5	3714·8	3719·1	3723·4	3727·7	3732·0	4·3
163	4 3736·3	3740·6	3744·9	3749·2	3753·5	3757·8	3762·1	3766·4	3770·6	3774·9	4·3
164	3779·2	3783·5	3787·8	3792·0	3796·3	3800·6	3804·9	3809·1	3813·4	3817·6	4·3
165	3821·9	3826·2	3830·4	3834·7	3838·9	3843·2	3847·4	3851·7	3855·9	3860·2	4·3
166	4 3864·4	3868·7	3872·9	3877·2	3881·4	3885·6	3889·9	3894·1	3898·3	3902·5	4·2
167	3906·8	3911·0	3915·2	3919·5	3923·7	3927·9	3932·1	3936·3	3940·5	3944·7	4·2
168	3949·0	3953·2	3957·4	3961·6	3965·8	3970·0	3974·2	3978·4	3982·6	3986·7	4·2
169	4 3990·9	3995·1	3999·3	4003·5	4007·7	4011·9	4016·0	4020·2	4024·4	4028·6	4·2
170	4032·7	4036·9	4041·1	4045·2	4049·4	4053·6	4057·7	4061·9	4066·0	4070·2	4·2
171	4074·3	4078·5	4082·6	4086·8	4090·9	4095·1	4099·2	4103·3	4107·5	4111·6	4·1
172	4 4115·7	4119·9	4124·0	4128·1	4132·3	4136·4	4140·5	4144·6	4148·7	4152·9	4·1
173	4157·0	4161·1	4165·2	4169·3	4173·4	4177·5	4181·6	4185·7	4189·8	4193·9	4·1
174	4198·0	4202·1	4206·2	4210·3	4214·4	4218·5	4222·6	4226·7	4230·8	4234·8	4·1
175	4 4238·9	4243·0	4247·1	4251·2	4255·3	4259·3	4263·4	4267·5	4271·5	4275·6	4·1
176	4279·8	4283·7	4287·8	4291·8	4295·9	4300·0	4304·0	4308·0	4312·1	4316·1	4·1
177	4320·2	4324·2	4328·3	4332·3	4336·4	4340·4	4344·4	4348·5	4352·5	4356·5	4·0
178	4 4360·5	4364·6	4368·6	4372·6	4376·6	4380·7	4384·7	4388·7	4392·7	4396·7	4·0
179	4400·7	4404·7	4408·8	4412·8	4416·8	4420·8	4424·8	4428·8	4432·8	4436·8	4·0
180	4440·8	4444·7	4448·7	4452·7	4456·7	4460·7	4464·7	4468·7	4472·6	4476·6	4·0
181	4 4480·6	4484·6	4488·5	4492·5	4496·5	4500·5	4504·4	4508·4	4512·4	4516·3	4·0
182	4520·3	4524·2	4528·2	4532·2	4536·1	4540·1	4544·0	4548·0	4551·9	4555·9	4·0
183	4559·8	4563·7	4567·7	4571·6	4575·6	4579·5	4583·4	4587·4	4591·3	4595·2	3·9
184	4 4599·2	4603·1	4607·0	4610·9	4614·9	4618·8	4622·7	4626·6	4630·5	4634·4	3·9
185	4638·4	4642·3	4646·2	4650·1	4654·0	4657·9	4661·8	4665·7	4669·6	4673·5	3·9
186	4677·4	4681·3	4685·2	4689·1	4693·0	4696·9	4700·8	4704·6	4708·5	4712·4	3·9
187	4 4716·3	4720·2	4724·1	4727·9	4731·8	4735·7	4739·6	4743·4	4747·3	4751·2	3·9
188	4755·0	4758·9	4762·8	4766·7	4770·5	4774·4	4778·2	4782·1	4786·0	4789·8	3·9
189	4793·7	4797·5	4801·4	4805·2	4809·1	4812·9	4816·8	4820·6	4824·5	4828·3	3·8

CHAP. IV.

Table of Values of $\frac{d^2}{w}s$ for Ogival-headed Shot.

v.	0	1	2	3	4	5	6	7	8	9	Diff.
f.s.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	+
190	4 4832·2	4836·0	4839·8	4843·7	4847·5	4851·4	4855·2	4859·0	4862·8	4866·7	3·8
191	4870·5	4874·3	4878·1	4882·0	4885·8	4889·6	4893·4	4897·3	4901·1	4904·9	3·8
192	4908·7	4912·5	4916·3	4920·1	4923·9	4927·7	4931·5	4935·3	4939·1	4942·9	3·8
193	4 4946·7	4950·5	4954·3	4958·1	4961·9	4965·7	4969·4	4973·2	4977·0	4980·7	3·8
194	4984·5	4988·3	4992·1	4995·8	4999·6	5003·4	5007·1	5010·9	5014·7	5018·4	3·8
195	5022·2	4025·9	5029·7	5033·4	5037·2	5040·9	5044·7	5048·4	5052·1	5055·9	3·7
196	4 5059·6	5063·4	5067·1	5070·8	5074·6	5078·3	5082·0	5085·7	5089·4	5093·1	3·7
197	5096·9	5100·6	5104·3	5108·0	5111·7	5115·4	5119·1	5122·8	5126·5	5130·2	3·7
198	5133·9	5137·5	5141·2	5144·9	5148·6	5152·3	5156·0	5159·6	5163·3	5166·9	3·7
199	4 5170·6	5174·3	5177·9	5181·6	5185·2	5188·9	5192·5	5196·2	5199·8	5203·4	3·6
200	5207·1	5210·7	5214·3	5218·0	5221·6	5225·2	5228·8	5232·5	5236·1	5239·7	3·6
201	5243·3	5246·9	5250·5	5254·1	5257·7	5261·3	5264·9	5268·5	5272·1	5275·7	3·6
202	4 5279·2	5282·8	5286·4	5290·0	5293·6	5297·2	5300·7	5304·3	5307·8	5311·4	3·6
203	5314·9	5318·5	5322·0	5325·6	5329·1	5332·7	5336·2	5339·7	5343·3	5346·8	3·5
204	5350·3	5353·8	5357·3	5360·9	5364·4	5367·9	5371·4	5374·9	5378·4	5381·9	3·5
205	4 5385·4	5388·9	5392·4	5395·9	5399·4	5402·9	5406·3	5409·8	5413·3	5416·7	3·5
206	5420·2	5423·7	5427·1	5430·6	5434·1	5437·5	5441·0	5444·4	5447·8	5451·3	3·5
207	5454·7	5458·1	5461·6	5465·0	5468·4	5471·9	5475·3	5478·7	5482·1	5485·5	3·4
208	4 5488·9	5492·3	5495·7	5499·1	5502·5	5505·9	5509·3	5512·7	5516·1	5519·4	3·4
209	5522·8	5526·2	5529·6	5532·9	5536·3	5539·7	5543·0	5546·4	5549·7	5553·1	3·4
210	5556·4	5559·8	5563·1	5566·4	5569·8	5573·1	5576·5	5579·8	5583·1	5586·4	3·3
211	4 5589·7	5593·0	5596·4	5599·7	5603·0	5606·3	5609·6	5612·9	5616·2	5619·5	3·3
212	5622·8	5626·1	5629·3	5632·6	5635·9	5639·2	5642·5	5645·7	5649·0	5652·3	3·3
213	5655·5	5658·8	5662·0	5665·3	5668·6	5671·8	5675·1	5678·3	5681·5	5684·8	3·2
214	4 5688·0	5691·2	5694·5	5697·7	5700·9	5704·2	5707·4	5710·6	5713·8	5717·0	3·2
215	5720·2	5723·4	5726·6	5729·9	5733·1	5736·3	5739·5	5742·6	5745·8	5749·0	3·2
216	5752·2	5755·4	5758·6	5761·8	5764·9	5768·1	5771·3	5774·4	5777·6	5780·8	3·2
217	4 5783·9	5787·1	5790·2	5793·4	5796·6	5799·7	5802·9	5806·0	5809·1	5812·2	3·1
218	5815·4	5818·5	5821·6	5824·8	5827·9	5831·0	5834·1	5837·3	5840·4	5843·5	3·1
219	5846·6	5849·7	5852·8	5855·9	5859·0	5862·1	5865·2	5868·3	5871·4	5874·4	3·1
220	4 5877·5	5880·6	5883·7	5886·8	5889·9	5893·0	5896·0	5899·1	5902·1	5905·2	3·1
221	5908·3	5911·3	5914·4	5917·4	5920·5	5923·6	5929·6	5929·6	5932·7	5935·7	3·0
222	5938·7	5941·8	5944·8	5947·8	5950·9	5953·9	5956·9	5959·9	5963·0	5966·0	3·0
223	4 5969·0	5972·0	5975·0	5978·0	5981·0	5984·0	5987·0	5990·0	5993·0	5996·0	3·0
224	5999·0	6002·0	6004·9	6007·9	6010·9	6013·9	6016·9	6019·8	6022·8	6025·8	3·0
225	6028·7	6031·7	6034·6	6037·6	6040·5	6043·5	6046·5	6049·4	6052·4	6055·3	3·0
226	4 6058·3	6061·2	6064·1	6067·1	6070·0	6072·9	6075·9	6078·8	6081·7	6084·7	2·9
227	6087·6	6090·5	6093·4	6096·3	6099·3	6102·2	6105·1	6108·0	6110·9	6113·8	2·9
228	6116·7	6119·6	6122·5	6125·4	6128·3	6131·2	6134·1	6137·0	6139·9	6142·8	2·9
229	4 6145·7	6148·6	6151·5	6154·4	6157·3	6160·2	6163·1	6166·0	6168·8	6171·7	2·9
230	6174·6	6177·5	6180·4	6183·3	6186·2	6189·1	6191·9	6194·8	6197·7	6200·6	2·9
231	6203·5	6206·4	6209·3	6212·1	6215·0	6217·9	6220·8	6223·7	6226·6	6229·5	2·9
232	4 6232·3	6235·2	6238·1	6241·0	6243·9	6246·8	6249·7	6252·6	6255·4	6258·3	2·9
233	6261·2	6264·1	6267·0	6269·9	6272·8	6275·7	6278·6	6281·5	6784·3	6287·2	2·9
234	6290·1	6293·0	6295·9	6298·8	6301·7	6304·6	6307·5	6310·4	6313·3	6316·2	2·9
235	4 6319·0	6322·0	6324·9	6327·7	6330·6	6333·5	6336·4	6339·3	6342·2	6345·1	2·9
236	6348·0	6350·9	6353·8	6356·7	6359·6	6362·5	6365·4	6368·3	6371·2	6374·1	2·9
237	6377·0	6379·9	6382·8	6385·7	6388·6	6391·5	6394·4	6397·3	6400·2	6403·1	2·9
238	4·6406·0	6408·9	6411·8	6414·8	6417·7	6420·6	6423·5	6426·4	6429·3	6432·2	2·9
239	6435·1	6438·0	6440·9	6443·8	6446·8	6449·7	6452·6	6455·5	6458·4	6461·3	2·9
240	6464·2	6467·1	6470·1	6473·0	6475·9	6478·8	6481·7	6484·6	6487·6	6490·5	2·9
241	4 6493·4	6496·3	6499·2	6502·2	6505·1	6508·0	6510·9	6513·8	6516·8	6519·7	2·9
242	6522·6	6525·6	6528·5	6531·4	6534·3	6537·3	6540·2	6543·1	6546·1	6549·0	2·9
243	6551·9	6554·9	6557·8	6560·7	6563·7	6566·6	6569·5	6572·5	6575·4	6578·3	2·9
244	4 6581·3	6584·2	6587·2	6590·1	6593·0	6596·0	6598·9	6601·8	6604·8	6607·7	2·9
245	6610·6	6613·6	6616·5	6619·5	6622·4	6625·3	6628·3	6631·2	6634·2	6637·1	2·9
246	6640·1	6643·0	6645·9	6648·9	6651·8	6654·8	6657·7	6660·6	6663·6	6666·5	2·9
247	4 6669·5	6672·4	6675·4	6678·3	6681·3	6684·2	6687·2	6690·1	6693·0	6696·0	2·9
248	6698·9	6701·9	6704·8	6707·8	6710·7	6713·7	6716·6	6719·6	6722·5	6725·5	2·9
249	6728·4	6731·3	6734·3	6737·2	6740·2	6743·1	6746·1	6749·0	6752·0	6754·9	2·9

CHAP. IV.

Table of Values of $\frac{d^3}{w}s$ for Ogival-headed Shot.

v.	0	1	2	3	4	5	6	7	8	9	Diff.
f.s.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	+
250	4 6757·8	6760·7	6763·7	6766·7	6769·6	6773·6	6775·5	6778·4	6781·4	6784·3	2·9
251	6787·3	6790·2	6793·1	6796·1	6799·0	6802·0	6804·9	6807·8	6810·8	6813·7	2·9
252	6816·6	6819·6	6822·5	6825·4	6828·4	6831·3	6834·2	6837·1	6840·1	6843·0	2·9
253	4 6845·9	6848·8	6851·8	6854·7	6857·6	6860·5	6863·5	6866·4	6869·3	6872·2	2·9
254	6875·1	6878·1	6881 0	6883·9	6886·8	6889·7	6892·6	6895·6	6898·5	6901·4	2·9
255	6904·3	6907·2	6910·1	6913·0	6915·9	6918·8	6921·7	6924·6	6927·5	6930·4	2·9
256	4 6933·3	6936·2	6939·1	6942·0	6944·9	6947·8	6950·6	6953·5	6956·4	6959·3	2·9
257	6962·2	6965·0	6967·9	6970·8	6973·7	6976·5	6979·4	6982·3	6985·1	6988·0	2·9
258	6990·9	6993·7	6996·6	6999·4	7002·3	7005·1	7008·0	7010·8	7013·7	7016·5	2·9
259	4 7019·4	7022·2	7025·0	7027·9	7030·7	7033·5	7036·4	7039·2	7042·0	7044·8	2·8
260	7047·7	7050·5	7053·3	7056·1	7058·9	7061·7	7064·5	7067·4	7070·2	7073·0	2·8
261	7075·8	7078·6	7081·4	7084·2	7087·0	7089·7	7092·5	7095·3	7098·1	7100·9	2·8
262	4 7103·7	7106·5	7109·2	7112·0	7114·8	7117·6	7120·3	7123·1	7125·9	7128·6	2·8
263	7131·4	7134·2	7136·9	7139·7	7142·4	7145·2	7147·9	7150·7	7153·4	7156·2	2·8
264	7158·9	7161·7	7164·4	7167·1	7169·9	7172·6	7175·4	7178·1	7180·8	7183·5	2·7
265	4 7186·3	7189·0	7191·7	7194·4	7197·1	7199·9	7202·6	7205·3	7208·0	7210·7	2·7
266	7213·4	7216·1	7218·8	7221·5	7224·2	7226·9	7229·6	7232·3	7235·0	7237·7	2·7
267	7240·4	7243·1	7245·8	7248·5	7251·2	7253·8	7256·5	7259·2	7261·9	7264·5	2·7
268	4 7267·2	7269·9	7272·5	7275·2	7277·9	7280·5	7283·2	7285·9	7288·5	7291·2	2·7
269	7293·8	7296·5	7299·1	7301·8	7304·4	7307·1	7309·7	7312·3	7315·0	7317·6	2·6
270	7320·2	7322·9	7325·5	7328·1	7330·8	7333·4	7336·0	7338·6	7341·2	7343·9	2·6
271	4 7346·5	7349·1	7351·7	7354·3	7356·9	7359·5	7362·1	7364·7	7367·3	7369·9	2·6
272	7372·5	7375·1	7377·7	7380·3	7382·9	7385·5	7388·1	7390·7	7393·3	7395·8	2·6
273	7398·4	7401·0	7403·6	7406·2	7408·7	7411·3	7413·9	7416·4	7419·0	7421·6	2·6
274	4 7424·1	7426·7	7429·3	7431·8	7434·4	7436·9	7439·5	7442·0	7444·6	7447·1	2·6
275	7449·7	7452·2	7454·8	7457·3	7459·8	7462·4	7464·9	7467·4	7470·0	7472·5	2·5
276	7475·0	7477·5	7480·1	7482·6	7485·1	7487·6	7490·1	7492·7	7495·2	7497·7	2·5
277	4 7500·2	7502·7	7505·2	7507·7	7510·2	7512·7	7515·2	7517·7	7520·2	7522·7	2·5
278	7525·2	7527·7	7530·1	7532·6	7535·1	7537·6	7540·1	7542·6	7545·0	7547·5	2·5
279	7550·0	7552·4	7554·9	7557·4	7559·9	7562·3	7564·8	7567·2	7569·7	7572·2	2·5
280	4 7574·6	7577·1	7579·5	7582·0	7584·4	7586·8	7589·3	7591·7	7594·2	7596·6	2·4
281	7599·0	7601·5	7603·9	7606·4	7608·8	7611·2	7613·6	7616·1	7618·5	7620·9	2·4
282	7623·3	7625·7	7628·2	7630·6	7633·0	7635·4	7637·8	7640·2	7642·6	7645·0	2·4
283	4 7647·4	7649·8	7652·2	7654·6	7657·0	7659·4	7661·8	7664·2	7666·6	7669·0	2·4
284	7671·3	7673·7	7676·1	7678·5	7680·9	7683·3	7685·6	7688·0	7690·4	7692·7	2·4
285	7695·1	7697·5	7699·8	7702·2	7704·6	7706·9	7709·3	7711·6	7714·0	7716·4	2·4
286	4 7718·7	7721·1	7723·4	7725·8	7728·1	7730·4	7732·8	7735·1	7737·5	7739·8	2·3
287	7742·1	7744·5	7746·8	7749·1	7751·5	7753·8	7756·1	7758·4	7760·8	7763·1	2·3
288	7765·4	7767·7	7770·0	7772·4	7774·7	7777·0	7779·3	7781·6	7783·9	7786·2	2·3
289	4 7788·5	7790·8	7793·1	7795·4	7797·7	7800·0	7802·3	7804·6	7806·9	7809·2	2·3
290	7811·5										

CHAP. IV.

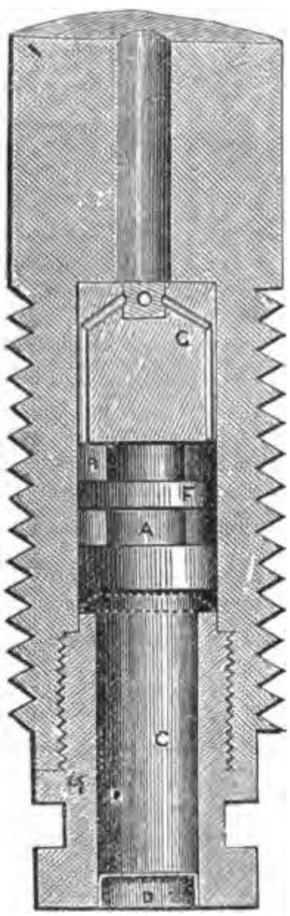
Pressure.

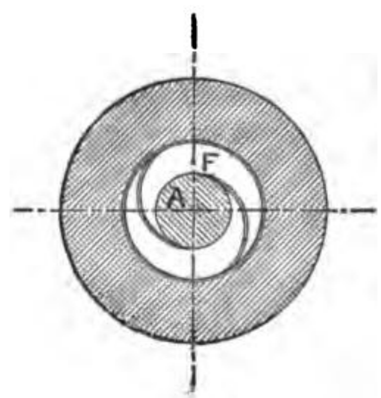
Pressure in the bore.

Several methods have been devised for measuring the pressure of powder-gas in the bore of a gun, but one system only is now followed at the Proof Butts. The instrument employed is a "crusher-gauge," and the principle lies in permitting the gas to compress a small solid cylinder of copper, and afterwards comparing the degree of compression with a table of measurements previously determined by mechanical means.

Crusher-gauge.

The crusher-gauge may have any convenient external form, but the arrangement for containing the copper is in all cases alike. For guns which have been devoted to experimental work or to the regular proof of gunpowder, steel bushes are made to be screwed into parts of the gun, which contain a crusher-gauge at the point. A drawing is given to illustrate this kind of plug, but it shows only the end, for its length will depend on the thickness of metal; and a square head must be given to the top for screwing it in and out of the gun.





A. The copper.
B. The chamber.
C. The piston.
D. The gas-check.
F. The watch-spring.
G. Air channels.
H. The nozzle.

THE CRUSHER-GAUGE.

The plug consists of a steel body partially provided with a screw-thread of the same dimensions as a copper vent-bush, and having a removable end called the "nozzle," which is pierced with a hole of definite sectional area (generally one-sixth of a square inch), and in this is fitted a piston. By removing the nozzle a chamber is disclosed into which the copper cylinder can be inserted, and there it must be held lightly (but not prevented from expanding) by a small piece of watch-

spring, which should keep it in the centre of the plug: one end rests against the bottom of the chamber or anvil, while the piston must be set in contact with the other. A small gas-check of brass is inserted in the nozzle after the plug has been got ready for use, to prevent any gas from penetrating into the gauge; air channels are provided at the upper end of the chamber leading into a vent, to prevent any re-action from compressed air which might counteract some pressure of the gas. The plug should be screwed into position with the nozzle exactly level with the surface of the inside of the gun. On firing, the pressure of the gas, acting upon the end of the piston, crushes up or compresses the copper; and the pressure corresponding to any measured reduction of length is ascertained from a table originally compiled from the compression of similar coppers in a statical testing machine.

This table has been calculated to give the result in tons of pressure per square inch of surface, when a piston $\frac{1}{8}$th of a square inch in section is used, with a half-inch cylinder of copper $\frac{1}{12}$th of an inch in sectional area. (See next page.)

Pressed coppers.

As copper cannot always be produced of exactly the same character and hardness, a limit of 5 per cent. is allowed for deviation from a fixed standard. Before use the half-inch cylinders are generally pressed in a machine under a definite force, say 6, 9, 12, or 15 tons per square inch, and the length or variation *per cent.* is recorded; then if a certain pressure were expected, a copper compressed nearly to that extent should be used. By this plan a more accurate amount of compression will be obtained, and a correction can be made for the known deviation from a standard quality of copper which corresponds with the table.

Hard and soft coppers.

For example: a copper pressed in the machine to 12 tons per square inch is found to show a diminution in length or *compression* of ·111 instead of ·107 as given in the table. The copper in this case is too "soft," and the degree of softness is about 3 per cent.; therefore 3 per cent. will have to be deducted from the pressure given in the table when the copper is further compressed after being used in a gun. Suppose this copper on being taken for an experiment to be crushed to the extent of ·142; by the table this is equivalent to a pressure of 14·9 tons. Deducting 3 per cent. the real pressure becomes 14·5.

When the coppers are hard, a similar correction has to be made by addition instead of subtraction.

Crushers in the cartridge.

If holes cannot be pierced in the gun for the reception of plugs, the crusher-gauge may be adapted for use in the cartridge. It is then contained in a short cylinder of steel, which is built into one end of the cartridge, so that when the latter is placed in the gun, the butt of the gauge should rest against the end of the bore. When prismatic powder is used, the gauge should be hexagonal in form, so as to take the place of one or two prisms which must be removed from the cartridge.

Gauges also have been fixed on a disc or annulus of copper to fit the end of the bore or curve of an obturating cup; but this arrangement has been given up as unnecessary.

Crushers in the base of the shot.

A gauge can also be set in the base of the projectile if prepared to receive it; the plug must then be screwed in the reverse way, so that the nozzle may be flush with the base of the shot.

Small pistons.

When very heavy pressures are expected, a gauge with a smaller piston can be substituted for the one of ordinary size. These are made of just half the usual area, viz., $\frac{1}{16}$th of a square inch in section, so that the same table of compressions may be used by simply doubling the pressures ascertained in the ordinary way. For very low pressures softer cylinders of lead are more suitable, but these require a different table of compressions.

CHAP. IV.

TABLE VIII.

TABLE giving the compression of copper cylinders, 0·5 inch long and 0·326 inch in diameter ($\frac{1}{12}$ of a square inch sectional area), and corresponding pressures per square inch in a crusher gauge, the piston of which is 0·461 inch in diameter ($\frac{1}{6}$ of a square inch sectional area).

Compression.	Pressure.	Compression.	Pressure.	Compression.	Pressure.	Compression.	Pressure.
inches.	tons.	inches.	tons.	inches.	tons.	inches.	tons.
·000	0·0	·100	11·0	·200	18·8	·300	32·5
·002	1·6	·102	11·1	·202	19·0	·302	32·9
·004	2·2	·104	11·3	·204	19·2	·304	33·4
·006	2·7	·106	11·4	·206	19·3	·306	33·9
·008	3·0	·108	11·5	·208	19·5	·308	34·4
·010	3·2	·110	11·7	·210	19·7	·310	34·9
·012	3·5	·112	11·9	·212	19·8	·312	35·4
·014	3·7	·114	12·0	·214	20·0	·314	35·9
·016	4·0	·116	12·2	·216	20·2	·316	36·4
·018	4·2	·118	12·3	·218	20·4	·318	36·9
·020	4·4	·120	12·5	·220	20·6	·320	37·4
·022	4·6	·122	12·6	·222	20·8	·322	37·9
·024	4·8	·124	12·7	·224	20·9	·324	38·5
·026	5·0	·126	12·9	·226	21·1	·326	39·1
·028	5·1	·128	13·1	·228	21·3	·328	39·7
·030	5·3	·130	13·2	·230	21·5	·330	40·2
·032	5·5	·132	13·3	·232	21·7	·332	40·7
·034	5·6	·134	13·5	·234	21·9	·334	41·3
·036	5·8	·136	13·6	·236	22·2	·336	41·9
·038	5·9	·138	13·8	·238	22·4	·338	42·3
·040	6·1	·140	14·0	·240	22·6	·340	42·9
·042	6·3	·142	14·1	·242	22·9	·342	43·5
·044	6·4	·144	14·3	·244	23·2	·344	44·1
·046	6·6	·146	14·4	·246	23·4	·346	44·8
·048	6·8	·148	14·6	·248	23·6	·348	45·5
·050	6·9	·150	14·7	·250	23·9	·350	46·1
·052	7·1	·152	14·9	·252	24·2		
·054	7·3	·154	15·0	·254	24·5		
·056	7·5	·156	15·2	·256	24·7		
·058	7·6	·158	15·3	·258	25·0		
·060	7·8	·160	15·5	·260	25·3		
·062	8·0	·162	15·7	·262	25·6		
·064	8·1	·164	15·9	·264	25·9		
·066	8·3	·166	16·0	·266	26·2		
·068	8·4	·168	16·1	·268	26·5		
·070	8·6	·170	16·3	·270	26·8		
·072	8·7	·172	16·5	·272	27·1		
·074	8·9	·174	16·6	·274	27·4		
·076	9·1	·176	16·8	·276	27·8		
·078	9·2	·178	17·0	·278	28·1		
·080	9·4	·180	17·1	·280	28·5		
·082	9·6	·182	17·3	·282	28·8		
·084	9·7	·184	17·5	·284	29·2		
·086	9.9	·186	17·6	·286	29·6		
·088	10·0	·188	17·8	·288	30·0		
·090	10·2	·190	18·0	·290	30·4		
·092	10·3	·192	18·2	·292	30·8		
·094	10·5	·194	18·3	·294	31·2		
·096	10·6	·196	18·5	·296	31·6		
·098	10·8	·198	18·7	·298	32·0		

PENETRATION OF ARMOUR.

We must now turn our attention from the work done on the gun to the work stored up in the projectile, which is a measure of its destructive effect, and, therefore, a convenient standard for comparing the relative power of guns. **Penetration.**

"Work" or energy is expressed in the case of a body in motion by the formula, **Work.**

$$E = \frac{w}{2g} v^2.$$

and the unit of measurement commonly taken is a "foot-ton." This kind of energy depends only upon the weight of the projectile and the velocity with which it is moving. The maximum energy will evidently be found at the muzzle, where velocity has a maximum value; and muzzle energy is often a convenient form of estimating the power of a gun. Penetration, however, depends upon the dimensions as well as the momentum of a shot, so two kinds of power exist which are measured respectively by energy in the shot at the muzzle and perforation of plate at a distance.

The question of guns *v.* armour has been under discussion for at least twenty years, but no permanent formula for penetration can be laid down because the amount will vary with so many conditions. The extent, in the first place, can only be ascertained by experiment, and although many series of experiments have been carried out, these were necessarily limited to a few natures of guns. The data so obtained have been used for establishing several formulæ, some of which will be explained in due course; but the dimensions of the projectiles are liable to change, and the quality of the armour has greatly improved, so it is impossible to bring perforation under one law, particularly when the velocities have a very wide range. **Guns *v.* armour.**

Captain Andrew Noble (formerly R.A.) was one of the first to draw out a formula for penetration; he assumed that if a projectile could just perforate a certain thickness of plate, the work or energy stored up in the shot just before striking was equivalent to a *shearing force*, the intensity of which would depend on the extent of the cylindrical surface of the hole punched through the plate, multiplied by some co-efficient which would vary with the circumstances of the experiment. It was discovered, however, that the resistance increased approximately with the *square* of the thickness, so the formula was first written thus:— **Noble's formula.**

$$E = \frac{wv^2}{2g} = \pi d\, t^2 \times k,$$

where w = weight of the projectile in tons.
v = striking velocity in feet per second.
d = diameter of the projectile in inches.
t = thickness of plate in inches.
k = the co-efficient obtained by experiment.

The assumption of the second power of t was no doubt empirical, and this had to be afterwards changed; but a formula of this kind seemed to be warranted by practice, and the value of k was determined accordingly.

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Energy per inch of shot's circumference

Since the resistance to shearing would clearly depend on the perimeter of the hole, Captain Noble aopted the "energy per inch of circumference" (e) as a more convenient method of connecting perforation with the force stored up in the projectile: thus

$$e = \frac{E}{\pi d} = \frac{wv^2}{2g \times 2240 \times \pi d} \text{ foot-tons.}$$

His formula, therefore, was of the form $t = (be)^c$, where b and c are constants depending on the nature of the projectile and the material of the plates; with ogival-headed chilled shot against wrought-iron plates these constants were at first given by the equation

$$t = \left\{\frac{e}{3{\cdot}18}\right\}^{\frac{1}{1{\cdot}6}} \text{ or } e = 3{\cdot}18\, t^{1{\cdot}6}.$$

A modification of this formula was prepared from the results of further experience by Major W. H. Noble, R.A., in which the constants were slightly changed, viz.:

$$t = \left\{\frac{e}{2{\cdot}52}\right\}^{\frac{1}{1{\cdot}6}} \text{ or } e = 2{\cdot}52\, t^{1{\cdot}6}$$

and this formula was generally used for the purpose of calculation for several years.

In 1878–80 further trials were made at Shoeburyness with guns of 3, 6, 8, and 9-inch calibre, of more modern type with velocities ranging both higher and lower than those previously given. These guns were fired against wrought-iron plates representing ship's armour which were sometimes solid and sometimes built up with several thicknesses of iron and backing. It was found that solid iron was superior to any system of plate; and comparing the results on solid iron with the calculated perforation, according to the formula $t = \sqrt[1{\cdot}6]{\frac{e}{2{\cdot}52}}$ and $t = \frac{E}{4{\cdot}733\pi r^2}$, it appeared that Noble's formula underrated the power of the smaller guns, while it overrated the larger natures when fired for velocities higher than 1,600 f.s.

Modification of Noble's formula.

A modification of the Noble formula was shortly afterwards published in the *Engineer* of the 5th November, 1880. A distinction was then made for the perforation of thin and thick plates, and the two formulæ were accordingly written as follows:—

$$\left.\begin{array}{l} e = 2{\cdot}41\, t^{1{\cdot}645} \text{ for plates between 4 and 10 inches.} \\ e = 0{\cdot}86\, t^{2{\cdot}035} \text{ for plates between 10 and 20 inches.} \end{array}\right\}$$

Maitland's formula.

Colonel Maitland about the same time had noticed that the amount of perforation, with projectiles of constant dimensions, was an indication of the striking velocity; and also that perforation could be expressed in terms of calibre by means of some function of this velocity. This law for perforation would be expressed as an equation by $t = kd$, where k is a function of the remaining velocity, to be qualified for any deviation from a standard description of projectile.

CHAP. IV.

The value of k was determined from the results of the most recent experiments, and it was found necessary to give it a different value for high and low striking velocities, the line being drawn at 700 f.s. when the value of $\frac{w}{d^3}$ in the shot was equal to ·37. Under these circumstances

$$\left.\begin{aligned} k &= \cdot 0008\ v \quad \text{when } v \text{ is less than 700 f.s.} \\ k &= \cdot 001\ v - \cdot 14 \text{ when } v \text{ is more than 700 f.s.} \end{aligned}\right\}$$

The varying proportions of shell, however, render it necessary to introduce into any formula for perforation the ratio of $\frac{w}{d^3}$, when dealing with a function of the striking velocity.* The expression for energy $\left(\frac{w}{2g}v^2\right)$ shows that momentum will vary directly with weight, but perforation will evidently depend *inversely* on the size of the hole that is punched. Diameter is the most convenient standard of measurement because it connects the calibre of gun with the size of the hole in the plate, and the third power must clearly be taken when dealing with cubic content.

So to give k a general value we must qualify the foregoing expressions where v occurs by the introduction of $\sqrt{\frac{\frac{w}{d^3}}{\cdot 37}}$ or $\frac{1}{\cdot 6083}\sqrt{\frac{w}{d^3}}$; the square root being extracted for association with the first power of velocity.

The formula where the striking velocity exceeds 700 f.s. therefore becomes:—

$$t = \frac{v}{608 \cdot 3}\sqrt{\frac{w}{d}} - \cdot 14d$$

which is that now practically employed, and is officially known as "Maitland's Formula of 1880."

t is the thickness of wrought-iron in *inches*, perforated by a service projectile of diameter d *inches*, weight w *pounds*, and striking velocity v foot-seconds.

Maitland's diagram.

Colonel Maitland also proposed a graphic method of calculating the remaining velocity (v) at any range for any initial velocity (V) by the use of a diagram and scale. The same diagram will then show the value to be given to k for any projectile in which the weight and dimensions are represented by the expression $\frac{w}{d^3}$ and hence perforation

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* The effect of varying the weight of a shot of given diameter may be illustrated by calculating the range over which a certain minimum velocity can be maintained. As an instance we may take the 6-inch B.L. guns, which fire projectiles of 80 and 100 lb. weight. The values of $\frac{w}{d^3}$ are here ·38 and ·47: then assuming a M.V. in each case of 1,900 f.s., a minimum velocity of 1,500 f.s. would be maintained over a range of 1,220 yards in the case of the 80-pr. gun, and of 1,545 yards in the case of the 6-inch Mark III.

Besides increase of range in favour of the heavier projectile, the perforations of wrought-iron plate with the same striking velocity would be 6·3 and 8·1 inches respectively; or at an equal range of 1,000 yards, and equal muzzle-velocity, about 8¼ inches with the 80-lb. shot, and 10¼ with the 100-lb. projectile.

CHAP. IV.

COLONEL MAITLAND'S DIAGRAM FOR DETERMINING REMAINING VELOCITY, TIME OF FLIGHT, AND PERFORATION.

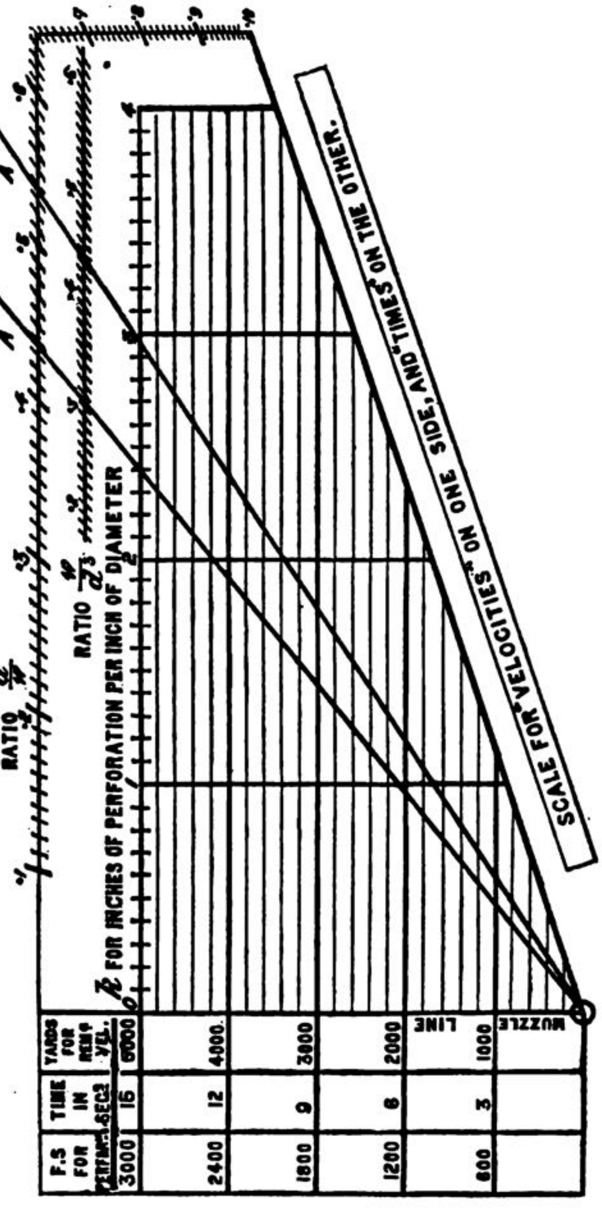

TABLE IX.

VALUES OF $\frac{W}{d^3}$

Where W = Weight of Projectile, and d = Diameter of Projectile.

$\frac{W}{d^3}$	CALIBRE OF GUNS.																							$\frac{W}{d^3}$
	3	4	5	6	6·3	6·6	7	8	9	9·2	10	10·4	11	12	12·5	13	14	15	16	17	18	19	20	
·2	5·2	12·4	24·4	42·3	49·1	56·2	67·1	100·5	143·4	153·2	197·0	221·7	261·9	340·4	385·0	433·3	541·8	666·9	810·0	972·2	1154·8	1358·8	1585·6	·2
·21	5·4	13·0	25·6	44·5	51·5	59·0	70·5	105·5	150·6	160·9	206·9	232·8	275·0	357·5	404·3	455·0	568·9	700·3	850·5	1020·8	1212·5	1426·8	1664·9	·21
·22	5·7	13·7	26·8	46·6	53·9	61·8	73·9	110·5	157·7	168·5	216·7	243·9	288·1	374·5	423·5	476·7	595·9	733·6	891·0	1069·5	1270·3	1494·7	1744·2	·22
·23	6·0	14·3	28·1	48·7	56·4	64·6	77·2	115·6	164·9	176·2	226·6	255·0	301·1	391·5	442·8	498·3	623·0	767·0	931·5	1118·1	1328·0	1562·7	1823·5	·23
·24	6·2	14·9	29·3	50·8	58·9	67·4	80·6	120·6	172·1	183·9	236·4	266·1	314·2	408·5	462·0	520·0	650·1	800·3	972·0	1166·7	1385·7	1630·6	1902·8	·24
·25	6·5	15·5	30·5	52·9	61·3	70·2	83·9	125·6	179·2	191·5	246·3	277·2	327·3	425·6	481·3	541·7	677·2	833·7	1012·5	1215·3	1443·5	1698·6	1982·1	·25
·26	6·7	16·1	31·7	55·0	63·8	73·1	87·3	130·6	186·4	199·2	256·1	288·3	340·4	442·6	500·5	563·3	704·3	867·0	1053·0	1263·9	1501·2	1766·5	2061·3	·26
·27	7·0	16·8	32·9	57·2	66·2	75·9	90·6	135·7	193·6	206·8	266·0	299·4	353·5	459·6	519·8	585·0	731·4	900·3	1093·5	1312·5	1558·9	1834·4	2140·6	·27
·28	7·3	17·4	34·2	59·3	68·7	78·7	94·0	140·7	200·7	214·5	275·8	310·4	366·6	476·6	539·0	606·7	758·5	933·7	1134·0	1361·1	1616·7	1902·4	2219·9	·28
·29	7·5	18·0	35·4	61·4	71·1	81·5	97·3	145·7	207·9	222·2	285·7	321·5	379·7	493·6	558·3	628·3	785·6	967·1	1174·5	1409·7	1674·4	1970·3	2299·2	·29
·3	7·8	18·6	36·6	63·5	73·6	84·3	100·7	150·7	215·1	229·8	295·5	332·6	392·8	510·7	577·5	650·0	812·7	1000·4	1215·0	1458·3	1732·2	2038·3	2378·5	·3
·31	8·0	19·2	37·8	65·6	76·0	87·1	104·1	155·8	222·2	237·5	305·4	343·7	405·9	527·7	596·8	671·7	839·7	1033·7	1255·5	1507·0	1790·0	2106·2	2457·7	·31
·32	8·3	19·9	39·0	67·7	78·5	89·9	107·4	160·8	229·4	245·1	315·2	354·8	419·0	544·7	616·0	693·4	866·8	1067·1	1296·0	1555·6	1847·6	2174·2	2537·0	·32
·33	8·6	20·5	40·3	69·9	80·9	92·7	110·8	165·8	236·6	252·8	325·1	365·9	432·1	561·7	635·3	715·0	893·9	1100·4	1336·5	1604·2	1905·4	2242·1	2616·3	·33
·34	8·8	21·1	41·5	72·0	83·4	95·5	114·1	170·8	243·8	260·5	334·9	377·0	445·2	578·7	654·6	736·7	921·0	1133·8	1377·0	1652·8	1963·1	2310·0	2695·6	·34
·35	9·1	21·7	42·7	74·1	85·9	98·3	117·5	175·9	250·9	268·1	344·8	388·0	458·3	595·8	673·8	758·3	948·1	1167·1	1417·5	1701·4	2020·9	2378·0	2774·9	·35
·36	9·3	22·4	43·9	76·2	88·3	101·2	120·8	180·9	258·1	275·8	354·6	399·1	471·4	612·8	693·0	780·0	975·2	1200·5	1458·0	1750·0	2078·6	2445·9	2854·2	·36
·37	9·6	23·0	45·1	78·3	90·8	104·0	124·2	185·9	265·3	283·4	364·5	410·2	484·5	629·8	712·3	801·7	1002·3	1233·8	1498·5	1798·6	2136·3	2513·9	2933·4	·37
·38	9·9	23·6	46·4	80·4	93·2	106·8	127·6	190·9	272·4	291·1	374·3	421·3	497·5	646·8	731·6	823·4	1029·4	1267·2	1539·0	1847·2	2194·1	2581·8	3012·7	·38
·39	10·1	24·2	47·6	82·6	95·7	109·6	130·9	196·0	279·6	298·8	384·2	432·4	510·6	663·9	750·8	845·0	1056·5	1300·5	1579·5	1895·9	2251·8	2649·7	3092·0	·39
·4	10·4	24·8	48·8	84·7	98·1	112·4	134·3	201·0	286·8	306·4	394·0	443·5	523·7	680·9	770·1	866·7	1083·6	1333·9	1620·0	1944·5	2309·5	2717·7	3171·3	·4
·41	10·6	25·5	50·0	86·8	100·6	115·2	137·6	206·0	293·9	314·1	403·9	454·6	536·8	697·9	789·3	888·4	1110·6	1367·2	1660·5	1993·1	2367·3	2785·6	3250·6	·41
·42	10·9	26·1	51·2	88·9	103·0	118·0	141·0	211·0	301·1	321·7	413·7	465·7	549·9	714·9	808·6	910·0	1137·7	1400·6	1701·0	2041·7	2425·0	2853·6	3329·8	·42
·43	11·2	26·7	52·5	91·0	105·5	120·8	144·4	216·1	308·3	329·4	423·6	476·7	563·0	731·9	827·8	931·7	1164·8	1433·9	1741·5	2090·3	2482·8	2921·5	3409·1	·43
·44	11·4	27·3	53·7	93·2	107·9	123·6	147·7	221·1	315·4	337·1	433·4	487·8	576·1	749·0	847·1	953·4	1191·9	1467·3	1782·0	2138·9	2540·5	2989·5	3488·4	·44
	3	4	5	6	6.3	6·6	7	8	9	9·2	10	10·4	11	12	12·5	13	14	15	16	17	18	19	20	
	Windage = ·04″					Windage = ·05″							Windage = ·06″											

TABLE IX—(*continued*).

VALUES OF $\frac{W}{d^3}$

Where W = Weight of Projectile, and d = Diameter of Projectile.

$\frac{W}{d^3}$	CALIBRE OF GUNS.																						$\frac{W}{d^3}$
	3	4	5	6	6·3	6·6	7	8	9	9·2	10	10·4	11	12	12·5	13	14	15	16	17	18	19	20	
·45	11·7	27·9	54·9	95·3	110·4	126·5	151·1	226·1	322·6	344·7	443·3	498·9	589·2	766·0	866·3	975·0	1219·0	1500·6	1822·5	2187·5	2598·2	3057·4	3567·7	·45
·46	11·9	28·6	56·1	97·4	112·9	129·3	154·4	231·1	329·8	352·4	453·1	510·0	602·3	783·0	885·6	996·7	1246·1	1533·9	1863·0	2236·1	2656·0	3125·3	3647·0	·46
·47	12 2	29·2	57·4	99·5	115·3	132·1	157·8	236·2	337·0	360·0	463·0	521·1	615·4	800·0	904·8	1018·4	1273·2	1567·3	1903·5	2284·7	2713·7	3193·3	3726·3	·47
·48	12·4	29·8	58·6	101·6	117·8	134·9	161·1	241·2	344·1	367·7	472·9	532·2	628·5	817·1	924·1	1040·0	1300·3	1600·6	1944·0	2333·4	2771·5	3261·2	3805·6	·48
·49	12·7	30·4	59·8	103·7	120·2	137·7	164·5	246·2	351·3	375·4	482·7	543·3	641·6	834·1	943·3	1061·7	1327·3	1634·0	1984·5	2382·0	2829·2	3329·2	3884·8	·49
·5	13·0	31·0	61·0	105·9	122·7	140·5	167·9	251·2	358·5	383·0	492·5	554·4	654·7	851·1	962·6	1083·4	1354·4	1667·3	2025·0	2430·6	2886·9	3397·1	3964·1	·5
·51	13·2	31·7	62·2	108·0	125·1	143·3	171·2	256·3	365·6	390·7	502·4	565·4	667·8	868·1	981·8	1105·0	1381·5	1700·7	2065·5	2479·2	2944·7	3465·1	4043·4	·51
·52	13·5	32·3	63·5	110·1	127·6	146·1	174·6	261·3	372·8	398·4	512·2	576·5	680·9	885·1	1001·1	1126·7	1408·6	1733·9	2106·0	2527·8	3002·4	3533·0	4122·7	·52
·53	13·7	32·9	64·7	112·2	130·0	148·9	177·9	266·3	380·0	406·0	522·1	587·6	693·9	902·2	1020·3	1148·4	1435·7	1767·4	2146·5	2576·4	3060·1	3600·9	4202·0	·53
·54	14·0	33·5	65·9	114·3	132·5	151·7	181·3	271·3	387·1	413·7	531·9	598·7	707·0	919·2	1039·6	1170·0	1462·8	1800·7	2187·0	2625·0	3117·9	3668·9	4281·2	·54
·55	14·3	34·2	67·1	116·4	134·9	154·5	184·6	276·4	394·3	421·3	541·8	609·8	720·1	936·2	1058·8	1191·7	1489·9	1834·1	2227·5	2673·6	3175·6	3736·8	4360·5	·55
·56	14·5	34·8	68·3	118·6	137·4	157·4	188·0	281·4	401·5	429·0	551·6	620·9	733·2	953·2	1078·1	1213·4	1517·0	1867·4	2268·0	2722·3	3233·4	3804·8	4439·8	·56
·57	14·8	35·4	69·6	120·7	139·8	160·2	191·4	286·4	408·6	436·7	561·5	632·0	746·3	970·3	1097·3	1235·0	1544·1	1900·7	2308·5	2770·9	3291·1	3872·7	4519·1	·57
·58	15·0	36·0	70·8	122·8	142·3	163·0	194·7	291·4	415·8	444·3	571·3	643·1	759·4	987·3	1116·6	1256·7	1571·1	1934·1	2349·0	2819·5	3348·8	3940·6	4598·4	·58
·59	15·3	36·6	72·0	124·9	144·7	165·8	198·1	296·5	423·0	452·0	581·2	654·1	772·5	1004·3	1135·8	1278·4	1598·2	1967·5	2389·5	2868·1	3406·6	4008·6	4677·6	·59
·6	15·6	37·3	73·2	127·0	147·2	168·6	201·4	301·5	430·2	459·6	591·0	665·2	785·6	1021·3	1155·1	1300·0	1625·3	2000·8	2430·0	2916·7	3464·3	4076·5	4756·9	·6
·61	15·8	37·9	74·4	129·1	149·6	171·4	204·8	306·5	437·3	467·3	600·9	676·3	798·7	1038·4	1174·3	1321·7	1652·4	2034·1	2470·5	2965·3	3522·1	4144·5	4836·2	·61
·62	16·1	38·5	75·7	131·3	152·1	174·2	208·1	311·5	444·5	475·0	610·7	687·4	811·8	1055·4	1193·6	1343·4	1679·5	2067·5	2511·0	3013·9	3579·8	4212·4	4915·5	·62
·63	16·3	39·1	76·9	133·4	154·5	177·0	211·5	316·5	451·7	482·6	620·6	698·5	824·9	1072·4	1212·8	1365·0	1706·6	2100·3	2551·5	3062·5	3637·5	4280·4	4994·8	·63
·64	16·6	39·7	78·1	135·5	157·0	179·8	214·8	321·6	458·8	490·3	630·4	709·6	838·0	1089·4	1232·1	1386·7	1733·7	2134·2	2592·0	3111·1	3695·3	4348·3	5074·1	·64
·65	16·9	40·4	79·3	137·6	159·4	182·7	218·2	326·6	466·0	497·9	640·3	720·7	851·1	1106·4	1251·3	1408·4	1760·8	2167·5	2632·5	3159·8	3753·0	4416·2	5153·3	·65
·66	17·1	41·0	80·6	139·7	161·9	185·5	221·6	331·6	473·2	505·6	650·1	731·8	864·2	1123·5	1270·6	1430·0	1787·9	2200·9	2673·0	3208·4	3810·8	4484·2	5232·6	·66
·67	17·4	41·6	81·7	141·8	164·4	188·3	224·9	336·6	480·3	513·3	660·0	742·8	877·3	1140·5	1289·8	1451·7	1814·9	2234·2	2718·5	3257·0	3868·5	4552·1	5311·9	·67
·68	17·6	42·2	83·0	144·0	166·8	191·1	228·3	341·7	487·5	520·9	669·8	753·9	890·3	1157·5	1309·1	1473·4	1842·0	2267·6	2754·0	3305·6	3926·2	4620·1	5391·2	·68
·69	17·9	42·8	84·2	146·1	169·3	193·9	231·6	346·7	494·7	528·6	679·7	765·0	903·4	1174·5	1328·3	1495·0	1869·1	2300·9	2794·5	3354·2	3984·0	4688·0	5470·5	·69
·7	18·2	43·5	85·4	148·2	171·7	196·7	235·0	351·7	501·8	536·2	989·5	776·1	916·5	1191·5	1347·6	1516·7	1896·2	2334·3	2835·0	3402·8	4041·7	4756·0	5549·8	·7
	3	4	5	6	6·3	6·6	7	8	9	9·2	10	10·4	11	12	12·5	13	14	15	16	17	18	19	20	
	Windage = ·04″					Windage = ·05″							Windage = ·06″											

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can be readily found. The values of $\frac{d^2}{w}$ and $\frac{w}{d^3}$ must be ascertained in each particular case, but tables have been prepared to save the trouble of this calculation. By a similar mode of procedure the "Time of Flight" can also be found by means of the same diagram, using the reverse side of the scale.

The mode of using the diagram can best be explained by working out an example.

Example. Suppose that it is required to find the remaining velocity (v), the time of flight (t), and the perforation (p) for the 12-inch B.L. gun at 2,000 yards when the M.V. is taken at 2,000 f.s.

For remaining velocity. (1) For remaining velocity. Since retardation depends upon the ratio of $\frac{d^2}{w}$, we must first ascertain the value of this expression; $\frac{d^2}{w} = \frac{144}{714} = 0{\cdot}20$. Now set the straight-edge or string, which should be pivoted at the intersection of the "zero" and "muzzle" lines on the left, to this value on the scale for $\frac{d^2}{w}$. Take the ruler, and using the velocity side apply 2,000 f.s. to the "muzzle line" at the point on the scale representing 2,000 yards range; then adjusting it to the parallel lines on the sheet read off at the intersection of the straight-edge with the velocity scale on the ruler, the tabular value to be given to v:—

$$v = 1695.$$

For time of flight. (2) For time of flight. Reverse the ruler and apply 1685 on the "Time" scale to the straight-edge in the same position as before, moving the ruler up and down parallel to itself until the initial velocity 2,000 f.s. coincide with the "muzzle-line." Then read off on that level the time of flight from the centre column of seconds:

$$t = 3{\cdot}25 \text{ seconds.}$$

For perforation. (3) For perforation. The value of $\frac{w}{d^3}$ (which may be found in the table) is 0·41 in this case.

Set the straight-edge to this quantity on the scale for $\frac{w}{d^3}$: then carrying the eye from 1695 on the scale of striking velocities for perforation along that line to the point where it cuts the straight-edge, and thence at right angles to the top of the diagram, a value of k will be found which will give the perforation in inches per inch of diameter of the shot. In this example $k = 1{\cdot}64$; so

$$p = 1{\cdot}64 \times 12 = 19{\cdot}68 \text{ inches.}$$

Col. Inglis's theory. Colonel Inglis, R.E., who has devoted much time to this subject, maintains that for each proportion of *diameter of shot to thickness of plate* (whatever their dimensions may be) a uniform amount of energy per unit of volume displaced is required to effect complete perforation, provided that the material and form of the projectile are always the same. Thus a 6-inch shot will have to exert as much energy in removing each cubic inch of iron when perforating a 6-inch plate as a 12-inch shot in perforating a 12-inch plate. He has also prepared a few diagrams which show the degree of perforation for certain guns, but these diagrams only hold good under fixed conditions of charge.

Captain Orde Browne's rule of thumb. Captain Orde Browne, late R.A., and now Lecturer at the R.A. Institution at Woolwich on Armour-plate, has suggested a short rule of thumb, which, if not accurate, may at any rate be found useful for calculating the chances of penetration before going into action. His rule is this:—" that a service projectile, for every 1,000 f.s, of striking

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velocity, or proportion above or below this amount, will nearly perforate a thickness of plate given by the calibre of gun."

For instance, a 12-inch shot with 1,000 f.s. striking velocity will almost perforate a plate 12 inches thick; with 1,500 f.s. velocity it will almost go through 18; and with 2,000 f.s. almost 24.

Putting this rule into the form of an equation, $t = \frac{v}{1000} d$; but here an assumption is made that the projectiles are of uniform character, in other words that $\frac{w}{d}$ is constant, otherwise some coefficient would have to be introduced into the formula.

This rule of thumb is very nearly correct when $\frac{w}{d^3}$ has a value of ·11; in service projectiles the value of this ratio is rather uncertain, and in muzzle-loading guns will often fall below this amount; but the rule is simple and fairly correct, and may be easily committed to memory. A table of remaining velocities for service guns is given below, from which it may be observed that the retardation for the same velocities varies from about 10 to 28 f.s. for each 100 yards range, inversely with the size of the gun.

TABLE X.

TABLE of Remaining Velocities in Projectiles fired with Full Charges.

Nature of Gun.	M.V.	At 500 yards.	At 1,000 yards.	At 1,500 yards.	At 2,000 yards.
R.M.L. GUNS.					
17·72-inch	1548	1496	1445	1396	1349
16 "	1590	1539	1489	1440	1393
12·5 " Mark I ..	1445	1385	1329	1276	1227
12·5 " Mark II ..	1575	1511	1421	1363	1308
12 " 35 tons ..	1390	1246	1196	1149	1108
12 " 25 tons ..	1292	1236	1179	1127	1085
11 "	1360	1253	1199	1149	1106
10 "	1379	1294	1228	1170	1118
9 "	1440	1322	1236	1160	1097
8 "	1384	1306	1213	1136	1074
7 " 7 tons ..	1561	1421	1296	1188	1097
7 " 6½ tons ..	1525	1388	1267	1164	1078
B.L. GUNS.					
16·25-inch	2020*	1965	1902	1840	1789
13·5 "	1960*	1902	1846	1790	1737
12 " Marks I to V	1892	1819	1741	1672	1605
10 " Mark I ..	2100*	2014	1932	1855	1779
9·2 " Marks I & II	1845	1764	1685	1608	1523
9·2 " Mark III ..	2050	1958	1870	1786	1704
8 " Mark III ..	1960	1841	1729	1620	1517
8 " Mark IV ..	2030	1907	1790	1680	1574
6 " 80-pr. ..	1880	1712	1555	1406	1278
6 " Mark II ..	1660	1536	1419	1309	1206
6 " Mark III ..	1850	1716	1589	1469	1357

* Estimated.

Energy per ton weight of gun.

We have now considered several methods of estimating power in a gun, such as total energy in the projectile, the energy per inch of circumference, and perforation of wrought-iron plate; we have also shown that this power will depend on the velocity, weight and dimensions of the shot; but for comparison of different pieces of ordnance and for contrasting our guns with those of other nations abroad, it will be convenient to go a step further, and estimate the proportion of power for each unit of weight in the gun. This comparison can be made most conveniently in the degree of energy imparted to the shot at the muzzle; foot-tons being the units of energy, and tons the units of weight in the gun. The calculation is simple, and a table has been drawn out below to show at a glance the relative merits by this particular standard of some of the guns in different countries of Europe. This method of comparison, however, may not always be quite satisfactory, for the factors of safety must of course be equally good; it has sometimes been a guide to manufacturers, but excessive development of power in pieces of mimimum weight must be followed by excessive recoil. The method of mounting then becomes a most serious question, and carriages are racked by the means taken to check the recoil. Under these circumstances it may often be better to give additional weight to the gun, especially when mounted in permanent works: such weight would not only assist in bringing the recoil under control, but it would give greater strength to the gun.

TABLE XI.

TABLE for Comparison of Power in British and Foreign Guns, per ton weight of gun, &c.

Gun.	Weight, tons.	Charge.		M.V.	Energy at the muzzle.		Perforation of wrought-iron armour-plate.		Remarks.
		Powder.	Projectile.		Total.	Per ton.	At muzzle.	At 1,000 yards.	
French ... 34 c.m.	51·6	...	...	1,962	...	...	29·1	25·7 (?)	
German... 35 c.m.	52	253·5	1,157	1,644	21,691	417·1	23	21	
British ... 12 in.	45	295	714	1,892	17,723	412·2	21·7	20·4*	
French ... 42 c.m.	75·4	617·3	1,726	1,738	36,628	485·8	27	24 (?)	
German... 40 c.m.	70·8	451	1,708	1,761	36,739	518·9	28·1	26·2	
Italian ... 40 c.m.	72	451	1,631	1,985	44,577	619·1	29·3	27·2	
British ... 13½ in.	67	520	1,250	1,960	33,810	504·7	29·1	27·3*	
Italian ... 43 c.m.	101	772	2,005	1,832	46,600	460	30·3	28·5	Elswick
British ... 16¼ in.	111	900	1,800	2,020	50,924	463	32·5	30·5*	guns

* Estimated.

THEORETICAL DETERMINATION OF MUZZLE VELOCITY, &c.

The following method for estimating the ballistic powers of a gun of new design is taken from the memoir "Researches on Explosives," by Capt. Noble (late R.A.) and Sir F. Abel, published in the Proceedings of the Royal Society in 1879.

A table (given below) was calculated from the data furnished by a laborious series of experiments. It sets forth the energy derivable from the explosion of gunpowder, in terms of the number of expansions of the charge; and from this table the muzzle energy can be deduced, and thence—knowing the weight of projectile—the muzzle velocity.

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TABLE XII.

GIVING the total work that dry gunpowder of the Waltham Abbey standard is capable of performing in the bore of the gun.

The unit of specific volume is 27·73 c.i. per lb.

Number of Volumes of Expansion.	Total work that Gunpowder is capable of performing.		Number of Volumes of Expansion.	Total work that Gunpowder is capable of peforming.	
	Per lb. burned, in foot tons.	Difference.		Per lb. burned, in foot tons.	Difference.
1·00	—	—	2·30	56·439	1·135
1·01	·980	·980	2·35	57·539	1·100
1·02	1·936	·956	2·40	58·605	1·066
1·03	2·870	·936	2·45	59·639	1·034
1·04	3·782	·912	2·50	60·642	1·003
1·05	4·674	·892	2·55	61·616	·974
1·06	5·547	·873	2·60	62·563	·947
1·07	6·399	·852	2·65	63·486	·923
1·08	7·234	·835	2·70	64·385	·899
1·09	8·051	·817	2·75	65·262	·877
1·10	8·852	·810	2·80	66·119	·857
1·11	9·637	·785	2·85	66·955	·836
1·12	10·406	·769	2·90	67·771	·816
1·13	11·160	·754	2·95	68·568	·797
1·14	11·899	·739	3·00	69·347	·779
1·15	12·625	·726	3·05	70·109	·762
1·16	13·338	·713	3·10	70·854	·745
1·17	14·038	·700	3·15	71·585	·731
1·18	14·725	·687	3·20	72·301	·716
1·19	15·400	·675	3·25	73·002	·701
1·20	16·063	·663	3·30	73·690	·688
1·21	16·716	·653	3·35	74·365	·671
1·22	17·359	·643	3·40	75·027	·662
1·23	17·992	·633	3·45	77·677	·650
1·24	18·614	·622	3·50	76·315	·638
1·25	19·226	·612	3·55	76·940	·625
1·26	19·828	·602	3·60	77·553	·613
1·27	20·420	·692	3·65	78·156	·603
1·28	21·001	·581	3·70	78·749	·593
1·29	21·572	·571	3·75	79·332	·583
1·30	22·133	·561	3·80	79·905	·573
1·32	23·246	1·113	3·85	80·469	·564
1·34	24·324	1·078	3·90	81·024	·555
1·36	25·371	1·047	3·95	81·570	·546
1·38	26·389	1·018	4·00	82·107	·537
1·40	27·380	·991	4·10	83·157	1·050
1·42	28·348	·968	4·20	84·176	1·019
1·44	29·291	·943	4·30	85·166	·990
1·46	30·211	·920	4·40	86·128	·962
1·48	31·109	·898	4·50	87·064	·936
1·50	31·986	·877	4·60	87·975	·911
1·52	32·843	·857	4·70	88·861	·886
1·54	33·681	·838	4·80	89·724	·863
1·56	34·500	·819	4·90	90·565	·841
1·58	35·301	·801	5·00	91·385	·820
1·60	36·086	·785	5·10	92·186	·801
1·62	36·855	·769	5·20	92·968	·782
1·64	37·608	·753	5·30	93·732	·764
1·66	38·346	·738	5·40	94·479	·747
1·68	39·069	·723	5·50	95·210	·731
1·70	39·778	·709	5·60	95·925	·715
1·72	40·474	·696	5·70	96·625	·700
1·74	41·156	·682	5·80	97·310	·685
1·76	41·827	·671	5·90	97·981	·671
1·78	42·486	·659	6·00	98·638	·657
1·80	43·133	·647	6·10	99·282	·644
1·82	43·769	·636	6·20	99·915	·633
1·84	44·394	·625	6·30	100·536	·621
1·86	45·009	·615	6·40	101·145	·609
1·88	45·614	·605	6·50	101·744	·599
1·90	46·209	·595	6·60	102·333	·589
1·92	46·795	·586	6·70	102·912	·579
1·94	47·372	·577	6·80	103·480	·569
1·96	47·940	·568	6·90	104·038	·558
1·98	48·489	·559	7·00	104·586	·548
2·00	49·050	·551	7·10	105·125	·539
2·05	50·383	1·333	7·20	105·655	·530
2·10	51·673	1·290	7·30	106·176	·521
2·15	52·922	1·249	7·40	106·688	·512
2·20	54·132	1·210	7·50	107·192	·504
2·25	55·304	1·172	7·60	107·688	·496

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Number of Volumes of Expansion.	Total work that Gunpowder is capable of performing.		Number of Volumes of Expansion.	Total work that Gunpowder is capable of performing.	
	Per lb. burned, in foot tons.	Difference.		Per lb. burned, in foot tons.	Difference.
7·70	108·177	·489	9·90	117·395	·366
7·80	108·659	·482	10·	117·757	·362
7·90	109·133	·474	11·	121·165	3·408
8·00	109·600	·467	12·	124·239	3·074
8·10	110·060	·460	13·	127·036	2·797
8·20	110·514	·454	14·	129·602	2·566
8·30	110·962	·448	15·	131·970	2·368
8·40	111·404	·442	16·	134·168	2·198
8·50	111·840	·436	17·	136·218	2·050
8·60	112·270	·430	18·	138·138	1·920
8·70	112·695	·425	19·	139·944	1·806
8·80	113·114	·419	20·	141·647	1·703
8·90	113·528	·414	21·	143·258	1·611
9·00	113·937	·409	22·	144·788	1·530
9·10	114·341	·404	23·	146·242	1·454
9·20	114·739	·398	24·	147·629	1·387
9·30	115·133	·394	25·	148·953	1·324
9·40	115·521	·388	30·	154·800	5·847
9·50	115·905	·384	35·	159·667	4·867
9·60	116·284	·379	40·	163·828	4·161
9·70	116·659	·375	45·	167·456	3·628
9·80	117·029	·370	50·	170·671	3·215

The data necessary for the calculation are—

The weight of the charge (in lbs.) = P.
The total volume of bore (in cb. in.) = B.
The volume of powder chamber (cb. in.) = C.
The weight of projectile (lbs.) = W.

and the process is as follows:—

The volume of gas generated at a density of unity is first obtained by multiplying P by 27·73, *i.e.*, the number of cb. in. occupied by 1 lb. of water at standard temperature, &c. Then the number of expansions in the chamber and bore are obtained by dividing C and B respectively by this product. Reference to the table shows the amount of work due to each of these expansions. The work done by the expansion in the chamber is considered lost as regards the projectile, and consequently this must for the purpose in hand be deducted from the work realisable from the total number of expansions in the bore—in other words, the tabular value of $\frac{C}{P \times 27{\cdot}73}$ must be deducted from that of $\frac{B}{P \times 27{\cdot}73}$. Of course if $C = P \times 27{\cdot}73$, and the density of the charge is unity (as explained at p. 236), no deduction will have to be made.

Example of calculating M.E.

Take, for example, the 8-inch B.L. gun, Mark III—

$$\text{Here } P = 100,\ B = 11837,\ C = 3050,$$

$$\text{and } \frac{B}{P \times 27{\cdot}73} = 1{\cdot}1.$$

The tabular value of this is 8·852.

The total expansion is—

$$\frac{11837}{100 \times 27{\cdot}73} = 4{\cdot}27,$$

the tabular value of which is 84·869.

Subtracting, we get an energy of 84·869 − 8·852 = 76·02 foot-tons per lb. of powder, or a total of 7602.

Percentage obtained as M.V.

The energy thus calculated represents the total theoretic energy derivable from the powder under the conditions given, and of course only a portion of it can be communicated to the projectile so as to appear in the form of muzzle velocity. The amount stored up in the

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projectile in this form is ascertained when the gun is fired and the proportion of this to the total amount as calculated (usually expressed as a percentage) is termed the "factor of effect."

"Factor of effect."

To ascertain the actual factor of any gun (whose muzzle velocity is known) we have to employ the formula connecting energy and velocity, viz.:—

$$E = \frac{w \times V^2}{2g},$$

having regard to the units employed.

For instance, for the factor of the gun above quoted the M.E. obtained (in foot-tons) is—

$$\frac{210 \times 1960^2}{64{\cdot}4 \times 2240} = 5594 \text{ foot-tons.}$$

Comparing this with the total calculated, viz., 7602, we obtain a factor of

$$\frac{5594}{7602} = {\cdot}7358, \text{ or } 73{\cdot}58 \text{ per cent.}$$

If the above method gave a perfectly accurate estimate of the energy derivable from the powder under the conditions named (or even of a definite proportion of the energy), of course the factors of effect would form an accurate estimate of the relative mechanical efficiency of different guns as working machines. But unfortunately the correction introduced for variations in density of the charge does not (as pointed out by the authors) effect more than an approximation, and consequently the factor fluctuates unduly from causes outside the gun as a machine.

Before, however, the ballistics of a new gun can be predicted by this method a suitable factor must be assigned, and with the knowledge now gained by practical experience, this is not difficult. *Cæteris paribus* it is found to vary with the calibre (a law observed by the authors in R.M.L. guns), but it also varies with the nature of the powder employed, the air spacing of the charge, the ratio of capacity of chamber to bore, and other minor conditions.

Table XIV.

Table XIV shows the factors as ascertained for the B.L. guns already fired. The M.V.'s given are those laid down as likely to be obtained under service conditions from practice carried out at Shoeburyness and elsewhere.

Calculation employed conversely.

Of course the above method can be (and is) employed conversely to determine the internal dimensions of a gun necessary to produce any desired result; certain conditions, such as calibre, weight of shot, and muzzle velocity, being generally laid down with reference to the effect to be produced on the range.

TABLE XIV.

TABLE giving Factor of Effect (with necessary data) for B.L. Guns.*

Nature of Gun.	Charge.			Capacity of		No. of Expansions.		Projectile.		Muzzle Energy.		
	Nature.	Weight.	Gravimetric Density.	Chamber.	Total Bore.	In Chamber.	Total.	Weight.	Muzzle Velocity realised.	Calculated per lb. of Powder (Table).	Realised per lb. of Powder.	Factor.
		lbs.		cubic ins.	cubic ins.			lbs.	f.s.	f. tons.	f. tons.	
12-pr.	S.P.	4	29·5 ·942	118	647	1·064	5·832	12·5	1,705	91·64	62·95	68·69
4-inch, 13 cwt.	R.L.G.[4]	3·25	38·9 ·718	126·5	776	1·404	8·610	25	1,180	84·74	74·25	87·62
4-inch, 22 cwt., I.	S.P.	12	38·4 ·722	461	1,474	1·386	4·429	25	1,738	59·71	43·62	73·03
4-inch, II., III., IV.	S.P.	12	34·8 ·797	417	1,570	1·253	4·718	25	1,900	69·61	52·15	74·92
5-inch, I., II., III.	S.P.	16	31·9 ·869	510	2,637	1·149	5·943	50	1,780	85·71	68·63	80·05
6-inch, 80-pr.	S.P.	34	33·9 ·818	1,155	4,827	1·225	5·118	80	1,880	74·65	57·68	77·27
6-inch, II....	P.[3]	34	40·9 ·678	1,390	5,109	1·474	5·419	100	1,660	64·98	56·18	86·48
6-inch, III.	P.[3]	42	32·9 ·843	1,380	5,020	1·185	4·310	100	1,850	70·20	56·5	79·25
8-inch, III.	Prism[1] Black	100	30·5 ·909	3,050	11,837	1·100	4·27	210	1,960	76·02	55·94	73·58
8-inch, IV.	Prism[1] Black	100	30·5 ·909	3,050	13,466	1·100	4·857	210	2,030	81·35	59·99	73·74
9·2-inch, I., II.	Prism[1] Brown	160	31·3 ·886	5,000	17,802	1·127	4·012	380	1,845	71·3	56·05	78·61
9·2-inch, III., IV., V.	Prism[1] Brown	175	28·6 ·970	5,000	21,682	1·030	4·468	380	2,050	83·89	63·27	75·43
12-inch, I., II., III., V.... ...	Prism[1] Brown	295	33·2 ·835	9,780	38,968	1·195	4·765	714	1,892	73·69	60·08	81·55

* This table represents the conditions in the guns as first issued. Some will be altered as to powder chamber and length of bore according to the details given in Chap. IV. The introduction of the cannelured band has slightly altered the chamber capacities of all. *Vide* Table XXXII., p. 302.

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TABLE XV.

For converting the densities of charges of powder expressed in cubic inches per lb. into gravimetric densities, assuming that 1 lb. of powder having a gravimetric density of 1·0 occupies a space of 27·73 cubic inches, the space occupied by 1 lb. of water.

27·73 = 1·00.

Cubic inches.	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
22	1·260	1·255	1·249	1·243	1·238	1·232	1·227	1·222	1·216	1·211
23	1·206	1·200	1·195	1·190	1·185	1·180	1·175	1·170	1·165	1·160
24	1·155	1·151	1·146	1·141	1·136	1·132	1·127	1·123	1·118	1·114
25	1·109	1·105	1·100	1·096	1·092	1·087	1·083	1·079	1·075	1·071
26	1·066	1·062	1·058	1·054	1·050	1·046	1·042	1·039	1·035	1·031
27	1·027	1·023	1·019	1·016	1·012	1·008	1·005	1·001	·997	·994
28	·990	·987	·983	·980	·976	·973	·970	·966	·963	·959
29	·956	·953	·950	·946	·943	·940	·937	·934	·930	·927
30	·924	·921	·918	·915	·912	·909	·906	·903	·900	·897
31	·894	·892	·889	·886	·883	·880	·877	·875	·872	·869
32	·867	·864	·861	·858	·856	·853	·851	·848	·845	·843
33	·840	·838	·835	·833	·830	·828	·825	·823	·820	·818
34	·815	·813	·811	·808	·806	·804	·801	·799	·797	·795
35	·792	·790	·788	·785	·783	·781	·779	·777	·775	·772
36	·770	·768	·766	·764	·762	·760	·758	·756	·753	·751
37	·749	·747	·745	·743	·741	·739	·737	·735	·734	·732
38	·730	·728	·726	·724	·722	·720	·718	·716	·715	·713
39	·711	·709	·707	·706	·704	·702	·700	·698	·697	·695
40	·693	·691	·690	·688	·686	·685	·683	·681	·680	·678
41	·676	·675	·673	·671	·670	·668	·666	·665	·663	·662
42	·660	·659	·657	·655	·654	·652	·651	·649	·648	·646
43	·645	·643	·642	·640	·639	·637	·636	·634	·633	·632
44	·630	·629	·627	·626	·624	·623	·622	·620	·619	·618
45	·616	·615	·613	·612	·611	·609	·608	·607	·605	·604
46	·603	·601	·600	·599	·598	·596	·595	·594	·592	·591
47	·590	·589	·587	·586	·585	·584	·582	·581	·580	·579
48	·578	·576	·575	·574	·573	·572	·570	·569	·568	·567
49	·566	·565	·564	·562	·561	·560	·559	·558	·557	·556
50	·555	·553	·552	·551	·550	·549	·548	·547	·546	·545
51	·544	·543	·542	·540	·539	·538	·537	·536	·535	·534
52	·533	·532	·531	·530	·529	·528	·527	·526	·525	·524
53	·523	·522	·521	·520	·519	·518	·517	·516	·515	·514
54	·513	·512	·511	·510	·510	·509	·508	·507	·506	·505
55	·504	·503	·502	·501	·500	·500	·499	·498	·497	·496

PART II.

CHAPTER I.

SMOOTH-BORE ORDNANCE.

Smooth-bore ordnance replaced by rifled guns.—Bronze and cast-iron guns.—Manufacture by casting.—List of pieces retained in the service.—S.B. wrought-iron guns.—Classes of ordnance.—Guns.—Shell guns.—Carronades.—Howitzers.—Mortars.—L.S. and S.S.—Designation.—Length.—Nominal weight.—Preponderance.—Windage.—Natures of cast-iron ordnance.—Bronze ordnance.—Inspection, proof, and marking.—Venting.—Iron and copper bushes.—Cone and through bush.—Vent channel.—Lines on S.B. guns.—Line of metal.—Millar's sights.—Conditions for adjustment.—Radius distance.—Clearance angle.—Wood tangent scales.—Sets of hexagonal scales for S.S.—Sights for bronze ordnance.—Wood side scales.—Stores.—Table of S.B. ordnance and charges.

S.B. ordnance still retained in the service.

SMOOTH-BORE ordnance have now been almost entirely replaced by rifled guns in our navy and in the forts of this country; but many pieces may be found in the armaments abroad, and some are still retained for service at home, so it is necessary for artillerymen to be more or less acquainted with this description of ordnance. For some particular objects and in certain positions S.B. pieces may be undoubtedly useful; for instance, mortars are retained for high-angle fire; and S.B. guns are now being converted into breech-loaders for the defence of flanks in permanent works, and to cover short avenues of approach at close quarters.

Bronze and cast iron.

There are two distinct kinds of S.B. pieces which are classified in the first instance by the material of which they are made, viz., bronze and cast iron. All were manufactured in a similar manner; they were cast roughly and solid in vertical moulds, breech downwards, with a "dead-head" of great length at the muzzle, which was afterwards cut off to ensure the metal being sound in the whole of the gun: the piece was then bored out to calibre.

List of pieces.

The variety of these pieces at one time was exceedingly great, but in 1865 two lists were made out, A and B, which prepared the way for reduction of number, and limited the natures to be eventually retained in the service (see § 1140). List A is republished on the following page; it is a table of S.B. pieces which are still to be considered available for use. List B was almost equally long, and comprised all

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TABLE XVI.

(List A.)

Table showing the Weight, Length, Calibre, Radius for Sighting, &c., of the Cast-iron and Bronze Ordnance, which are still retained in the Service.

	Nature and Service.	Nominal Weight.	Nominal Length.		Calibre.	Radius.		Clearance Angle.	By whom and when introduced.	Remarks.
						Short.	Long.			
		Cwt.	Ft.	In.	Ins.	Ins.	Ins.	Degs.		
Cast-Iron Guns.	8-in. L.S. & S.S....	65	9	0	8·05	56·0	112·23	5½	Millar, 1834.	
		60	8	10	8·05	56·0	110·225	5	Millar, 1831.	
		54	8	0	8·05	48·0	100·715	5	Dundas, 1840.	
	68-pr. L.S. only ...	112*	10	10	8·12	59·8	132·4	4½	Dundas, 1841.	
	,, L.S. & S.S....	95	10	0	8·12	58·0	122·1	5	Dundas, 1846.	
	42-pr. L.S. only ...	84*	10	0	6·97	56·5	121·5	4½	Monk, 1843.	
		67*	9	6	6·93	54·3	118·0	4	Dundas.	
	32-pr. L.S. only ...	63	9	7	6·41	55·5	116·6	4	Millar.	
	,, L.S. & S.S....	58	9	6	6·375	55·0	117·895	4	Dundas, 1847.	
	,, L.S. & S.S....	56	9	6	6·41	55·0	112·81	4	Blomefield.	
	,, L.S. & S.S., A.	50	9	0	6·375	50·0	109·25	5	Monk, 1838.	
	,, L.S. & S.S., B.	45	8	6	6·35	48·0	103·625	5	Monk, 1838.	
	,, L.S. & S.S., C.	42	8	0	6·35	46·3	97·62	5	Monk, 1838.	
	,, L.S. only ...	48 & 50	8	0†	6·41	50·0	97·0	5½	Blomefield, Millar, & Dickson.	
	,, L.S. only ...	40	7	6†	6·35	40·5	85·1	7	Congreve ...	Bored up in 1830, from 24-pr. of 42 cwt.
	,, L.S. only ...	39	7	6†	6·375	43·0	89·8	5	Blomefield......	Bored up in 1830, from 24-pr. of 40 cwt.
	,, L.S. & S.S....	32	6	6	6·3	39·0	78·0	6½	Blomefield......	Bored up in 1830, from 24-pr. of 33 cwt.
	,, L.S. & S.S....	25	6	0	6·3	36·5	74·0	6	Dundas, 1845.	Has only two muzzle mouldings.
	24-pr. L.S. only ...	50	9	6	5·823	54·6	112·75	4	Blomefield.	
		48	9	0†	5·823	51·5	107·0	4	Blomefield.	
		20	6	0	5·823	34·0	70·75	5	Blomefield. ...	Bored up from 12-pr., 22 cwt.
	18-pr. L.S. only ...	42	9	0	5·292	51·5	107·0	4	Blomefield.	
		38	8	0†	5·292	46·5	95·75	4	Blomefield.	
	12-pr.	34	9	0	4·623	51·0	107·5	4	Blomefield.	
		33	8	6	4·62	48·5	101·2	4	Blomefield ...	For drill and saluting.
	9-pr.	28	8	6	4·2	48·0	101·25	4	Blomefield.	
		24	7	0	4·2	41·0	84·1	4	Blomefield ...	For saluting.
	6-pr.	17	6	0	3·668	35·5	72·0	4½	Blomefield ...	For drill or saluting.
	Carronades 32-pr. ...	17	4	0	6·25	23·0	—	—	1779.	
	Carronades 24-pr. ...	13	3	8	5·68	20·5	—	—		
	Howitzers 10-in. L.S. only	42	5	0	10·0	—	60·3	—	Millar, 1852.	
	Howitzers 8-in. ...	22	4	2	8·0	—	48·0	—	Millar, 1852.	
	Mortars 13-in. S.S.	100	5	4	13·0	—	—	—	N.P., 1857.	
		100	4	5	13·0	—	—	—	O.P. or Blomefld.	
		81	3	2	13·0	—	—	—		
	Mortars 13-in. L.S. ...	36	3	4	13·0	—	—	—	Millar.	
	Mortars 10-in. S.S. ...	52	3	10	10·0	—	—	—	Blomefield.	
	Mortars 10-in. L.S. ...	18	2	5	10·0	—	—	—	Millar.	
	Mortars 8-in. L.S. ...	9	2	2	8·0	—	—	—	Millar.	
Bronze.	Guns 12-pr. L.S. ...	18	6	6	4·623	—	78·1	—		
	Guns 9-pr. L.S. ...	13	6	0	4·2	—	71·0	—		
	Guns 6-pr. L.S. ...	6	5	0	3·668	—	59·6	—		
	Guns 3-pr. L.S. ...	3	4	0	2·91	—	47·56	—		
	...	2½	3	0	2·91	—	35·5	—		
	Howitzers 24-pr. L.S. ...	13	4	8	5·72	—	56·0	—	Millar.	
	Howitzers 24-pr. S.S. ...	13	4	8	5·72	—	56·0	—	Millar.	
	Howitzers 12-pr. L.S. ...	6	3	9	4·58	—	45·0	—	Millar.	
	Howitzers 12-pr. S.S. ...	6	3	9	4·58	—	45·0	—	Millar.	
	Mortars 4⅖-in. L.S. ...	2¼	1	10	4·52	—	22·5	—	1738.	Coehorn.
	Mortars 5⅗-in. L.S. ...	1¼	1	3	5·62	—	—	—	1742.	Royal.
	Mortars 4⅖ in. L.S. ...	¾	1	1	4·52	—	—	—	1733.	Coehorn.

Note.—A few pieces have been struck out from this list as originally published, in consequence of their having been since pronounced obsolete.

* Retained only until the few that now remain are superseded by Rifled Guns.
† These guns have been issued in large numbers for the Volunteer service.

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those natures which were pronounced obsolete; but it was ordered at the same time that where any of the latter were mounted they should be retained on the works until they were replaced in due course. Probably they have all been exchanged by this time.

Cast-iron guns in 1545.

Cast-iron ordnance were manufactured in England as early as 1545, but bronze pieces had been made prior to that date, for the founding of bronze was apparently understood before the art of smelting iron had arrived at any degree of perfection.

Brass foundry at Woolwich.

The brass foundry at Woolwich was established in 1717, and there most of our bronze ordnance have been manufactured; some natures are still in existence, such as the 4⅖-inch howitzer and the Coehorn mortar, which have been made from the time of its first establishment.

Supply of cast-iron guns.

Cast-iron guns were supplied by contractors according to designs which were furnished to them, and these were proved on delivery by government officials.

S.B. wrought-iron guns.

In 1864, when the use of armour-plate on vessels of war raised the question of penetration and power of guns, the Admiralty proposed the construction of large S.B. *wrought-iron* guns. Two natures were accordingly made, 100 and 150-prs., which were built up on the Armstrong system of coils. More powerful results, however, were obtained from the smaller rifled guns which were adopted shortly afterwards for general service; so the manufacture of these S.B. pieces was soon discontinued. The 150-pr. is now obsolete; but the 100-prs. are still used by the navy for drill. These two pieces were the last natures of S.B. muzzle-loading ordnance introduced into our service, and they are the only S.B. guns made of other material than bronze or cast iron.

Classes of ordnance.

S.B. ordnance are classified as guns, carronades, howitzers, and mortars; and all these, with the exception of carronades, have been made both in brass and cast iron.

Guns.

"Guns" may be defined as those pieces which have a length of at least 12 calibres and upwards, and which are adapted for firing either shot or shell.

Shell guns.

Two guns, however, the 8 and 10-inch, were made only for shell; these differ from other guns in having "gomer" chambers, that is to say, a conical termination to the bore, and in being shorter and lighter in proportion to their calibre.

Carronades.

Carronades have a length of about 7 calibres, and the powder chamber is cylindrical, axially situated, but of smaller diameter than the bore. They differ from guns in external appearance in being small, and tapering at the muzzle, where they are furnished with a projecting rim instead of a swell to facilitate loading on board ship; they have no trunnions, but are secured to the carriage by a loop and bolt underneath the middle of the piece.

Howitzers.

Howitzers are not unlike shell guns; they are adapted only for firing shells, and are intended for horizontal or ricochet fire. Their length varies from 5 to 10 calibres.

Mortars.

Mortars are suitable only for high-angle or vertical fire. Their length is about 3 or 4 calibres, and the trunnions are placed at the extremity of the breech instead of being near the centre of gravity.

Gomer chambers.

All mortars, howitzers, and shell guns have gomer chambers except the 4⅖-inch bronze howitzer, which is chambered cylindrically.

L.S. and S.S.

Each nature of ordnance was formerly made either for land or sea service, although a few pieces were common to both. S.S. ordnance were furnished with breeching loops, and some with housing blocks also; but in other respects they differ generally from L.S. pieces only in small fittings and stores.

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Designation. S.B. guns which were made for firing solid shot are designated by the weight of the shot in pounds, and if necessary by the weight of the piece also; as, for instance, the 68-pr. of 95 cwt.; those natures which were intended only for firing shell are named by their calibre in inches, the weight of the piece being added as before when required, *e.g.*, the 8-inch mortar of 9 cwt.

Bronze howitzers are an exception to this rule, for being generally associated with guns, they are distinguished in the same manner, viz.: as 12, 24, and 32-pr. howitzers, although they never fired solid shot of those weights.

Where there is more than one pattern of the same calibre and weight, the length should be specified also as a further mark of distinction.

Length. Length is measured from the muzzle to the rear edge of the base-ring on the breech, except in mortars which are measured "over all," that to say, from the face of the muzzle to the extreme end of the breech taken parallel to the axis of the piece.

Nominal weight. The weights given in the table are termed "nominal," because there is often a difference of 2 or 3 cwt. in pieces of the same nature.

Preponderance. Preponderance is the term which is used to express the statical pressure on the elevating screw or coin, when the axis of the piece is horizontal.

Windage. Windage is usually defined as the difference between the diameter of the bore and the diameter of the shot, but properly speaking it is the difference between the sectional areas of the projectile and of the bore of the gun. In old guns the windage allowed was one-twentieth the diameter of the shot; but in those of more modern date it is only 0·1 of an inch in small natures, and 0·15 in heavy guns. Windage, of course, should be as little as possible, for besides allowing the shot to make indentations in the bore and causing irregularity of flight, a great deal of powder gas escapes by this passage, and a sacrifice of powder is entailed. This loss was computed to be equivalent to one-fourth or even one-third of the charge.

Natures of Cast-iron Ordnance.

A few remarks will be offered now in connection with the different natures of ordnance mentioned in Table XVI.

8-inch. 8-inch shell guns at one time formed part of the siege train, and were also used for the flanks of forts and for permanent works. Many of 65-cwt. have been converted into 64-pr. R.M.L guns. There are but few of the 54-cwt. and none of the 60-cwt. pattern now mounted in land service batteries.

68-pr. The 68-pr. of 112 cwt. was the heaviest cast-iron piece in our service, but very few are now left. There were, however, many of 95 cwt., for these were much used as pivot guns and for the sea faces of forts; a large number of these have been converted into 80-pr. R.M.L. guns.

42-pr. 42-prs. are rare, but a few may be found in remote batteries, especially abroad.

32-pr. 32-prs. were formerly the principal armament of all classes of vessels, and hence we have many descriptions varying in length as well as in weight. The different amount of windage allowed from time to time has caused a difference in their calibres for the projectiles were always the same; the charges also vary with the description of gun. The 58 and 56-cwt. guns were the patterns most commonly used, and

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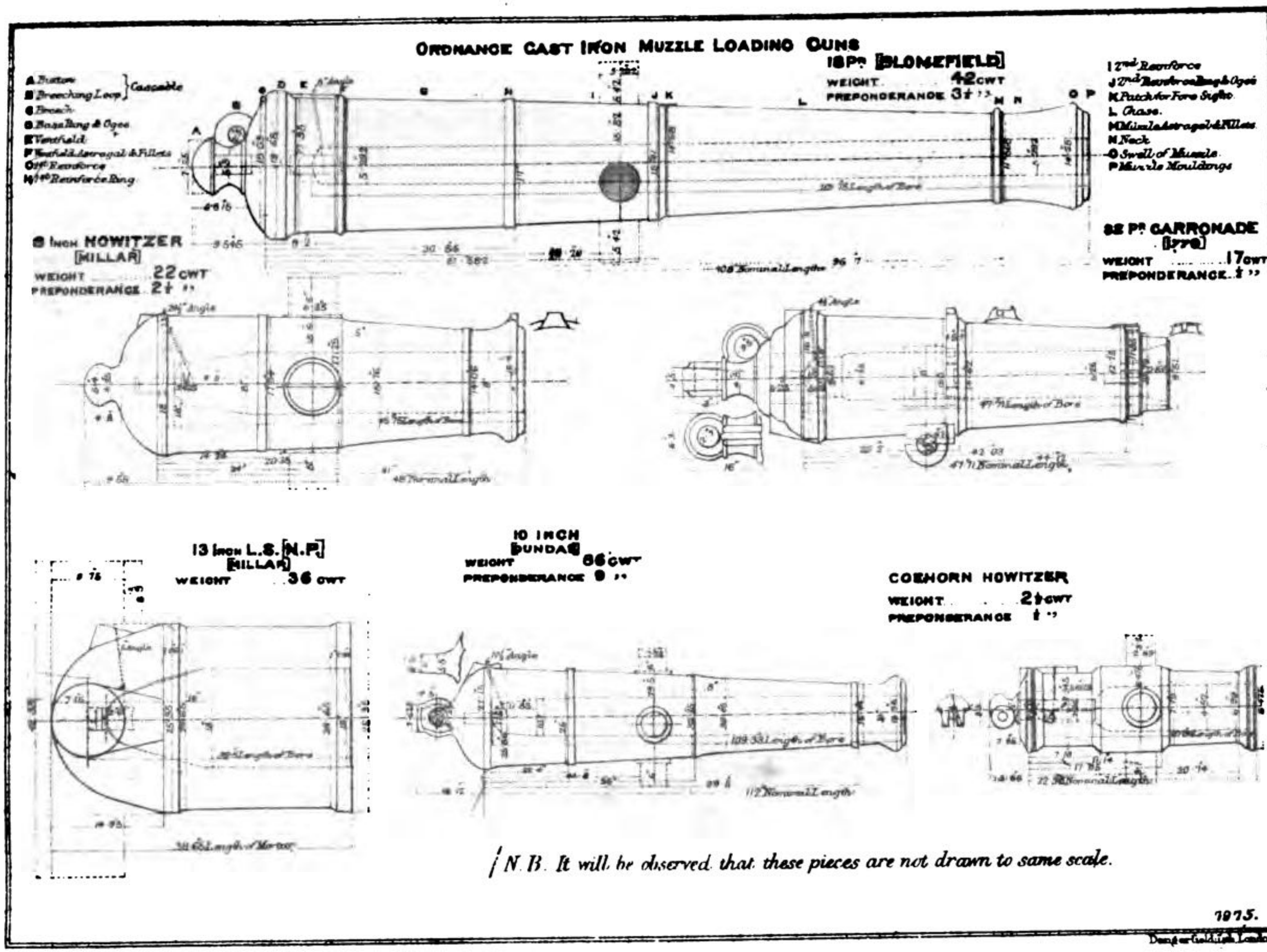

58-cwt. gun has been converted in very large numbers on the Palliser principle, into 64-pr. R.M.L. guns.

Monk's A, B, and C 32-pr. guns still exist, but will rarely be met with. The 48 and 50-cwt. guns are issued indiscriminately to be mounted on the same nature of carriage, and they are bracketed together in Annual Returns. These as well as the 39 and 40-cwt. guns have been issued in large quantities to Volunteers.

Bored up guns. The 32-prs. of 40, 39, and 32 cwt. are bored-up guns, having been originally 24-prs.

The 25-cwt. gun is a light 32-pr., which, though a shot gun, may be distinguished by having only two muzzle mouldings.

24-pr. 24-prs. have been exclusively assigned to land service; many of these have been issued to Volunteers.

18-pr. A few 18-prs., both of 42 and 38 cwt., may still be found in the flanks of large works.

12, 9, and 6-pr. The 6, 9, and 12-pr. cast-iron guns are now only used for saluting and drill.

Carronades. Carronades may be found in the flanks of a few works, and they are used also in the sea service for drill.

Iron Howitzers. Iron howitzers were mounted only in flanks and similar positions where a very short range was required.

Mortars. S.S. mortars of 13 and 10-inch calibre were originally intended for "mortar vessels," but they are now used for coast defence. They are much heavier, and have narrower chambers than the mortars of corresponding calibre for L.S. There is also an 8-inch mortar which was made for land service.

*Bronze Ordnance.**

Guns. There are four natures of smooth-bore bronze guns: 12, 9, 6, and 3-prs. These are nearly alike in exterior appearance, resembling the earlier patterns of cast-iron guns. By an order, dated November, 1859, a dispart patch is to be added to every bronze gun before issue.

Howitzers. Of bronze howitzers there are also four natures, two of which, the 24 and 12-pr., are common to land and sea service; these are similar in pattern, but for S.S. they are provided with a breeching loop, and the breech is rounded off that the rope may not be cut by the base ring. The 32-pr. is only used for L.S. The $4\frac{2}{5}$-inch is retained for colonial and mountain equipment: it is of exceptional form, very short, and has a cylindrical chamber.

Mortars. The bronze mortars may still be found useful in mountain warfare, in the defence of a besieged fortress, and perhaps in the advanced trenches of an attack.

Inspection, Proof and Marking before issue.

The following were the tests applied in the Royal Gun Factory to cast-iron pieces on delivery by any contractor.

Proof. They were examined for flaws in the metal and for gauge and concentricity of bore; then two proof rounds were fired with a heavy charge and a service shot pressed home with a junk wad or wooden wedge. The gun was afterwards proved by water pressure, and finally examined with a lamp passed down the bore.

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* A large quantity of bronze ordnance has now been sold as old metal, but some of these pieces exist, especially in India, and in our possessions abroad.

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Marks.

Guns which endured the test were weighed, marked, and registered. On the first reinforce were engraved the number by which the gun was entered in the R.G.F. books, the broad arrow, the exact weight of the piece, and year of proof; thus—

8736
↑
52—1—10
1858.

On the left trunnion were already marked the manufacturer's initials or the name of the foundry, the manufacturing number, and year of casting. Bronze ordnance are marked in a somewhat similar way, but the register number is engraved in Roman letters on some part of the piece, not always in the same spot, the foundry number being generally between the trunnions on the underneath side of the gun.

This system of marking was not introduced until 1857; prior to that date guns were not marked in any regular manner. The weight was sometimes engraved under the cascable. On bored-up guns the new weight and date of boring up were placed on the first reinforce. Carronades were marked near the elevating patch.

Royal Badge.

The Royal Badge is to be found on the first reinforce of most natures of guns; but on the 68-pr. it is placed over the breech. Bronze guns have also the monogram of the Master-General of the Ordnance on the chase.

Venting.

Venting.

Prior to issue a S.B. gun is vented and fitted with sights. This work is now done in the Arsenal, but it may have to be performed at out-stations, for these pieces were formerly issued to gun-wharves and depôts of ordnance before this work had been done.

The vent channel was formerly a mere hole drilled through the metal and usually inclined from the top of the breech down to the end of the bore; but in consequence of the enlargement of vents in the guns used at the sieges of 1812–13, experiments were carried out at Woolwich as to the advantage of using bushes of different material, which were to be screwed into the gun and renewed as often as the vent channel became too much enlarged. Bushes proved to be very successful, and copper was found to be the material best suited for the purpose, so the Board of Ordnance directed that all guns should be bushed.

In 1844 it was ordered that only iron bushes should be used, because it was thought that a galvanic action was set up between the copper and iron, which might be the cause of corrosion. Experiments in 1855 proved that this was not really the case, so the use of copper bushes was resumed, and that of iron at the same time discontinued. No better material has since been discovered, especially when it is hardened by hammering.

From 1855 to the present date all guns have been bushed before issue, but prior to that date they were generally issued unbushed. Mortars were never bushed before issue, but some have been copper-bushed afterwards.

Cone and through bushes.

Copper bushes vary in size, in diameter, and in pitch of the thread. The service bushes, however, are now reduced to two kinds, which are known as the "Cone" and "Through." These are all tapped with a screw of 7 threads to the inch, but they vary in length according to the thickness of metal in the breech of the gun. A square head is furnished for the operation of screwing in and adjustment, but this and all surplus length is cut off when it has been properly fixed in the gun.

The operation will be described in Part IV, in connection with the repair of these guns which is commonly known as re-venting.

The vent channel has a diameter of ·22 of an inch; but this is slightly enlarged at the orifice in sea-service guns, to suit the quill friction tube.

When any piece of ordnance is bushed for the first time a cone bush is invariably put in, for the cone assists in securing a tight fit. After the metal of the bore has been worn away round the bush (even to a considerable extent) the gun may be vented again, perhaps two or three times, with another cone bush set deeper in the gun; last of all, a through bush must be used, and this requires very careful adjustment.

The nature of bush is generally expressed by a symbol \C/ or \T/; but when stamped on a gun the following letters are placed on the cascable as an indication of the nature of bush. On first issue—

$\left.\begin{array}{r}CV\\ N\\ C\end{array}\right\}$ meaning "copper vent, new gun, cone bush."

After rebushing the N should be obliterated, and when a through bush is put in the C should be hammered out also.

The initial of the out-station at which the gun is revented should also be stamped underneath the letters which refer to the vent.

Exceptional bushes.

Old guns may be found with various exceptional bushes, and these have been differently marked; for instance, LC means "long cone," and IV "iron vent"; there are also copper bushes with 6 threads to the inch, both cone and through. These exceptions must be carefully noted when reventing a gun, because a special bush may be necessary again, but there are very few now to be met with.

Lines on S.B. Guns.

Certain lines are required on guns for the adjustment of sights and other arrangements for pointing or laying the gun. These are now always engraved before issue, but in depôts abroad there may be guns which have not been lined up to the present. There are four principal lines to be marked on a S.B. gun.

Line of metal.

(1) The "Line of Metal," which is a line extending from the base ring to the swell of the muzzle, representing the intersection of the upper surface of the gun with a vertical plane passing through the axis of the piece when the trunnions are placed horizontal. It may be obtained in the following manner:—

The gun being levelled across the trunnions, a wood batten is placed in the bore, long enough to project some feet beyond the muzzle. This batten must have parallel sides; it should also be painted white on the upper surface and be bisected by a pencil line down the centre.

The surface of the batten is then levelled transversely, and, a T square being placed upon it, the position of the pencil line is squared up against the face of the muzzle.

A wood straight-edge is next placed on the top of the gun against the T square, and the edge of this and the centre line of the batten are brought into the same vertical plane by the eye. The line thus obtained is lightly marked on the swell of the muzzle and on the base ring. The T square should now be reversed and the same operation gone through on the other side; if the lines do not quite coincide at the breech the

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mean may be taken between them. It is then cut permanently on the muzzle and breech of the gun.

Horizontal axis.

(2) The "line of horizontal axis." This is marked on the right side of the gun, being obtained when the right trunnion is upwards, by a similar process to that by which the line of metal is found. It is engraved on the muzzle, breech, and right trunnion.

Quarter-sight lines.

(3) The "quarter-sight lines." These are marked on either side of the piece at the breech and muzzle, just sufficiently above the horizontal axis to clear the trunnions and capsquares; they furnish the zero or point-blank line for the quarter-sight scales.

Quarter-sight scale.

Before the introduction of Millar's sights all cast-iron guns were laid by means of the quarter-sight scales; these were engraved on the base ring on each side of the gun, the zero being the quarter-sight line, and the scale reading to 3 degrees elevation. The graduation was obtained from a template which was made for each nature of gun, whereby the degrees of a tangent scale (calculated to the radius distance between the base ring and a notch on the muzzle) could be projected on the curved surface of the breech.

Quarter-sight scales are now marked only on L.S. guns up to the 32-pr. inclusive.

Vertical line.

(4) The "vertical line." Upon the right trunnion the axis line is bisected and a vertical line is engraved at right angles to it. A special plate has been made for marking this line, which can be adapted by inserting a pin in different holes to trunnions of different diameter.

Sights.

Millar's sights.

The sights used with cast-iron* ordnance are known as Millar's sights. These consist of (*a*) a foresight of gun-metal, attached by screws to the gun on the second reinforce; and (*b*) a half round brass tangent scale,† sliding in a gun-metal block, which is secured to the breech.

Angle of attachment.

Pieces of sheet lead are placed between the sights and the gun, to facilitate adjustment and to prevent the heads of the screws from being broken off by the concussion of firing. In order to clear the breech when pushed down in the socket the hind-sight is attached at an angle of 76 degrees with the axis.

The mode of adjusting Millar's sights is at follows:—Having carefully levelled the gun across the trunnions, the fore and hind sights must be adjusted to fulfill the following conditions.

1st. They must be set at the exact distance apart, as given in Table XVI, for the radius distance of the particular gun.

2nd. When the scale is at zero the line joining the tops of the hind-sight and fore-sight must be parallel to the axis of the piece.

3rd. When the scale is raised to the "clearance angle" or full elevation marked on it, the tops of the two sights and the highest point on the muzzle must be in a straight line.

4th. The line of sight must be made to coincide with the vertical plane which passes through the line of metal and axis.

A special dummy sight is used in the first place in lieu of a fore-sight set loosely on the gun, which, with the hind-sight, is adjusted by hand until the conditions are fulfilled. An angular level is supplied to set

* Iron howitzers excepted, which are sighted in a similar manner to bronze guns.

† For S.S. this scale is hexagonal, and made of gun-metal.

the scale to its inclination of 76 degrees. The positions for the screw holes on the gun are then marked with a scriber through the holes previously drilled in the sight blocks, and punched through the lead packing. A drill-post is supplied for this purpose, and care must be taken to drill the holes perpendicular to the face of the block, so that the heads of the screws may rest fairly upon it; the holes are afterwards tapped.

The hind-sight should be fixed first. When this is done the scale must be raised to the clearance angle, and a silk thread is stretched from the bottom of the notch on the hind-sight to the bottom of the notch at the muzzle.

The dummy fore-sight is now exchanged for the real one, which is adjusted by hand under the silk cord at the proper distance from the rear face of the hind-sight. The screw holes being drilled and tapped as before, the sight is screwed on to the gun. The top is then filed down to the level of the cord, and the position of the ridge being marked on it, the sight must be removed to a bench for the side slopes to be filed. When screwed on once more the position is carefully tested to make sure that all the conditions are strictly fulfilled.

The sights and lead packing are stamped with the number of the gun, and the screws should also be marked for the holes to which they have been fitted.

When the guns are mounted and the sights kept in store, the holes should be plugged with preserving screws; but these must be removed if the guns are shifted, because the screw-heads are liable to be broken off, and the holes should be then filled with tallow or grease.

Short radius. The distance between these sights on the gun is termed the "short radius," because this is the distance for which the short tangent scales have been graduated.

Clearance angle. In using Millar's sights it will be found that at a certain elevation the muzzle of the gun will begin to interfere with the line of sight: this elevation is termed the "clearance angle," and may be defined as the degree of elevation when a line through the top of the notch on the tangent sight and the top of the fore-sight coincides with the notch on the muzzle. For higher degrees of elevation it becomes necessary to use the muzzle notch as a fore-sight, and the distance of this from the tangent sight is called the "long radius." **Long radius.** A long radius implies greater length of divisions on a tangent scale, and therefore a longer hind-sight, so for elevations above the clearance angle special arrangements are made which differ for land and sea service.

Wood tangent scales. For L.S. this supplementary scale is made of wood, and called the "wood tangent scale"; it is graduated from the clearance angle up to extreme elevation, about 10 degrees; it has also a degree scale from zero to the clearance angle though nor intended for use, and there is a yard scale engraved on it from point blank to extreme range.

At the back of the wood tangent scale is a brass staple which fits on to the head of the hind-sight when raised to its full elevation; and at the bottom is a plate shaped to fit on the block, so that it can be fixed to the ordinary hand-sight for use.

Tangent scales for bronze ordnance. With bronze ordnance a half-round brass tangent scale is used which works in a socket drilled in the metal of the gun. This socket is fitted with a spring, and the scale has a small stud at the bottom which prevents its being removed unless the spring is first taken out. The scale is clamped by a set-screw, but this is a separate store. The notch on a dispart patch at the muzzle serves as a fore-sight.

High head for S.S. All S.S. tangent sights for the S.B. bronze ordnance are furnished with a high head, that the line of sight may be clear of the friction

tube, guide-plate, and pin. The fore-sight in consequence must be equally high.

Wood-side scales.

As an alternative method of laying, "wood side-scales" are provided for 32-prs. of 32 and 25 cwt., and also for 24-pr. bronze howitzers when mounted on S.S. carriages with elevating screws. They are graduated to 12 degrees for elevation, and to 6 degrees for depression; the radius distance for the scale being the distance between the axis of the trunnion and the cross-cut on the horizontal line on the base-ring to which the side-scale is applied. For adjustment in the first instance the bar must be cut to such length that when placed on a step of the carriage and held perfectly upright, the zero line should coincide with the axis of the gun, when the latter is horizontal and the ship on an even keel. Elevation or depression can then be given by means of the side-scale in connection with the ship's pendulum or other means for ascertaining the heel of the vessel, when owing to smoke the gun cannot be laid by its sights.

Small Stores.

Small stores.

The following is a list of other stores for S.B. ordnance which are supplied by the Royal Gun Factory:—

Pricker, or priming iron.		Apron vent.
Vent punch.		Vent plug.
Vent bit.		Wrench.
Friction tube pin.	For S.S. only.	Preserving screws.
Lanyard guide.	For S.S. only.	Shot bearer.
Pendulum.	For S.S. only.	Spikes, common and spring.

Pricker or priming iron.

The pricker or priming wire is a rod of iron slightly pointed at one end, with a ring at the other. The term "priming wire" is adopted in the navy. For garrison service and large guns it is 12 inches long, for field service $7\frac{1}{2}$.

Vent punch.

A vent punch is supplied for cleaning the vent from any hard substance which cannot be removed with the pricker. These are of steel, and have a strong round head so as to bear hammering. There are four sizes, varying in length from 8 to 22 inches to suit different vents.

Aprons vent.

Aprons vent are small pieces of sheet lead for covering the vent and head of the tangent scale on howitzers and bronze guns. There are two sizes, large for iron howitzers, and small for bronze ordnance.

Vent bit.

Vent bits are also supplied for L. and S.S., they consist of wrought-iron-rods having a bit formed at one end, and a ring at the other; they are used for removing any slight burs which may be thrown up by the action of the powder gas in the vent.

Friction tube pin.

The friction tube pin consists of a small piece of steel threaded on the lower portion and formed into a pin. It is screwed into the gun to the left front of the vent in cast-iron ordnance, and to the right front in bronze; it is intended to support the lead of the S.S. quill tube, the loop of which is hooked over the pin.

Lanyard guide.

A lanyard guide is a small fitting for the lanyard to pass through to ensure a direct pull upon the tube. It is screwed into the surface of the piece on the opposite side of the vent to the friction tube pin. A cross-head serves to loop up the lanyard.

Pendulum.

A pendulum was formerly used to show the angle at which a vessel was heeling, that correction might be made in the elevation when laying a gun

Vent plug.

A vent plug consists of a vulcanised disc of indiarubber, with leather stem. It is employed for protecting the vents of ordnance when exposed to the weather.

Wrench.

The wrench is a small iron instrument with four arms, one of which is a wrench for sight screws, another for the friction tube pin, a third is a turnscrew, and the fourth is a tommy. An old pattern wrench may be met with sometimes consisting only of the turnscrew and wrench.

Shot bearer.

Bearers for shot or shell are supplied to 68-pr. guns and all ordnance of larger calibre, including the 100-pr. wrought-iron guns.

Of spikes there are two sorts, viz., "common" and "spring."

Common spikes.

The common spike is a conical piece of hard steel about 3 inches long. When it is desirable to disable a gun for some time, a spike of this kind may be hammered into the vent, and the top broken off. A gun well spiked in this manner cannot be made serviceable again without being revented, for which purpose hollow drills are supplied with each set of venting tools.

Spring spikes.

A gun may be rendered temporarily useless with a "spring spike": this consists of a steel rod with a flat head at the top and a spring near the bottom, so that when the end has passed into the bore the spring opens out and the spike cannot be easily removed. When the gun is recaptured, however, the spike can be taken out by pressing back the spring with a rammer: a small notch is cut on the head of the spike to show the position of the spring—*i.e.*, the side which must be turned towards the muzzle for its extraction.

For L.S. there are five lengths of spring spikes, viz.: A, 15·5-inch; B, 12·5-inch; C, 9·2-inch; D, 6-inch; E, 3·5-inch. Any others that may be in store have been declared obsolete, but not if on Artillery charge. The ordnance for which these are suitable are enumerated in the table below.

The length of a spike is measured from the head to the top of the spring.

The Navy are supplied only with the shorter natures, which are suitable for spiking field guns.

CHAP. I.

Description of Ordnance.	Description of spring spike which can be utilized.
Bronze smooth-bore guns :—	
12-pr., 18 cwt.	D
9-pr.	D
6-pr., 6 cwt.	D
3-pr.	—
Bronze smooth-bore howitzers :—	
4⅖-inch Coehorn, 2¼ cwt.	—
24-pr., 13 cwt.	D
12-pr., 7 cwt.	D
Bronze smooth-bore mortars :—	
5½-inch, 1¼ cwt.	—
Cast-iron smooth-bore guns :—	
8-inch, 65, 60, and 54 cwt.	B
68-pr., 95 cwt.	B
42-pr., 84 cwt.	B
42-pr., 67 cwt.	C
32-pr., of all natures (except 25 cwt.)	C
24-pr., 50 and 48 cwt.	C
24-pr., 20 cwt.	C
18-pr., 42 and 38 cwt.	C
18-pr., 20 and 15 cwt.	C
12-pr., 34 and 33 cwt.	C
9-pr.	C
6-pr., 17 cwt.	D
32-pr., 25 cwt.	D
Cast-iron smooth-bore howitzers :—	
10-inch, 42 cwt.	C
8-inch, 22 cwt.	C
Cast-iron smooth-bore mortars :—	
10-inch, 18 cwt.	C
8-inch, 9 cwt.	C

CHAP. I.

TABLE XVII.—SMOOTH-

(Corrected up to

		Ordnance.[j] Service.	Weight.	Length.	Bore. Calibre.	Bore. Length.	Preponderance.	Charge.[m] Exercising and Saluting. Blank, R.L.G. or L.G.	Charge. Service. L.G.[n] or R.L.G.[3]
			cwt.	ft. in.	in.	ft. in.	cwt.	lb. oz.	lb. oz.
Bronze. Guns.	12-pr.	L	18	6 6	4·623	6 2½	2·3	2 0	4 0
	9-pr.	L	13½	5 11·4	4·2	5 7·74	1·5	1 8	2 8
	6-pr.	L & S	6	5 0	3·668	4 9·47	0·75	1 0	1 8
	3-pr.	L	3	4 0	2·913	3 10	—	0 12	0 12
	,, ...	L	2½	3 0	2·913	2 10	—	0 10	0 10
Bronze. Howitzers.	32-pr.	L	17	5 3	6·3	5 1¼	2·0	2 0	3 0
	24-pr.	L & S	12½	4 8·6	5·72	4 7·15	1·0	1 8	2 8
	12-pr.	L & S	6½	3 9·2	4·58	3 7·8	0·5	1 0	1 4
	4⅖-in. ...	L	2½	1 10	4·52	1 8·86	0·5	0 4	0 8
Bronze. Mortars.	5½-in. royal ...	L	1¼	1 3·1	5·62	0 11·94	—	—	0 7
	4⅖-in. coehorn	L	¾	1 1	4·52	0 10¼	—	—	0 5
Cast-Iron. Carronades.	68-pr.	L	36	5 4	8·05	5 2	2·3	—	5 0
	42 pr.	L	22	4 5	6·84	4 7	1·0	—	3 8
	32-pr.	L	17	3 11·71	6·25	3 11¾	0·5	—	2 11
	24-pr.	L	13	3 8	5·68	3 7¼	0·3	—	2 0
Cast-Iron. Guns.	68-pr.	L	112[a]	10 10	8·12	10 3½	10·8	8 0	18 0
	,, ...	L & S	95[a]	10 0	8·12	9 5·9	10·5	8 0	16 0
	10-in.	L & S	86[a]	9 4	10·0	9 1·33	9·0	8 0	12[i] 0
	8-in.	L & S	65[b]	9 0	8·05	8 9·27	8·0	6 0	10 0
	,, ...	L & S	60[b]	8 10	8·05	8 7½	6·2	6 0	10 0
	,, ...	L & S	54[a]	8 0	8·05	7 9¾	6·7	6 0	8 0
	42-pr.[c] ...	L	84[d]	10 0	6·97	9 6¾	9·0	6 0	14 0
	,, ...	L	67[e]	9 6	6·935	9 0¾	9·0	6 0	10 8
	32-pr.	L	63[b]	9 7	6·41	9 3	5·25	5 0	10 0
	,, ...	L & S	58[a]	9 6	6·375	9 0·65	6·0	5 0	10 0
	,, ...	L & S	56[e]	9 6	6·41	8 11·2	6·0	5 0	10 0
	,, ...	L & S	50A[d]	9 0	6·375	8 7·08	7·0	—	8 0
	,, ...	L	48 or 50[bcj]	8 0	6·41	7 7	4·5	—	8 0
	,, ...	L & S	45B[d]	8 6	6·35	8 1½	6·0	—	7 0
	,, ...	L & S	42C[d]	8 0	6·35	7 7·2	5·7	—	6 0
	,, ...	L	40[ak]	7 6	6·35	7 0¼	3·5	—	6 0
	,, ...	L	39[ce]	7 6	6·375	7 1	3·5	—	6 0
	,, ...	L & S	32[ce]	6 6	6·3	6 0¼	3·2	—	5 0
	,, ...	L & S	25[a]	6 0	6·3	5 7·64	3·5	—	4 0
	,, B.L. converted Mark I[p]	L	42	8 1¼	6·3	7 2	3·5	—	3 0
	24-pr.	L	50[c]	9 6	5·823	8 11·41	4·5	3 0	8 0
	,, ...	L	48[e]	9 0	5·823	8 5¼	4·5	3 0	8 0
	,, ...	L	20[ce]	6 0	5·823	5 7¾	2·5	3 0	2 8
	18-pr.	L	42[e]	9 0	5·292	8 5·75	3·5	3 0	6 0
	,, ...	L	38[c]	8 0	5·292	7 6	3·5	3 0	6 0
	12-pr.	L	34[c]	9 0	4·623	8 6¼	3·5	2 0	4 0
	9-pr.	L & S	28[c]	8 6	4·[illegible]	8 0¾	2·7	1 8	3 0
Cast-Iron. Howitzers.	10-in.	L	42[b]	5 0	10·0	4 9¼	5·0	—	7 0
	8-in.	L	22[b]	4 0	8·0	3 9¾	2·5	—	4 0
Cast-Iron. Mortars.	13-in.	L & S	100	4 5	13·0	3 3	—	—	20[i] 0
	,, ...	L	36[b]	3 3·65	13·0	2 8·5	—	—	9 0
	10-in.	S	52[c]	3 10	10·0	2 11	—	—	9 8
	,, ...	L	18[b]	2 5	10·0	2 1	—	—	4 0
	8-in.	L	9[b]	2 1·23	8·0	1 8	—	—	2 0

[a] Dundas's. [b] Millar's. [c] Blomefield's. [d] Monk's. [e] Bored up.

[h] The weight of shot for bronze guns includes the riveted bottoms.

[i] The maximum charge to be used when firing carcasses from the 13-inch S.S. mortar is to be 16 lbs.; and from the 10-inch gun 8 lbs. [j] Dickson. [k] Congreve gun.

BORE ORDNANCE.

1st December, 1883.)

SHELL.								SHOT.		
Empty.				Bursting Charge.						
Common.	Diaph. shrapnel.	Mortar.	Naval.	Common shell, L.G.	Diaph. shrapnel, R.F G.F.G. or pistol.	Mortar, Shell, L.G.	Naval, Shell, L.G.	Case.[h]	Grape.	Solid.
lb oz.	lb. oz.	lb. oz.	lb. oz.	lb. oz.	drs.	lb. oz.	lb. oz.	lb. oz.	lb. oz.	lb. oz.
8 9	10 3	—	—	0 7	24	—	—	16 15½	—	12 8
—	7 12½	—	—	—	18	—	—	13 9	—	9 4
—	5 0	—	—	—	10	—	—	8 6	—	6 3
—	—	—	—	—	—	—	—	4 7	—	3 1½
—	—	—	—	—	—	—	—	4 7	—	3 1½
22 5	28 3	—	—	1 5	50	—	—	21 7	—	—
16 12	21 0	—	—	1 0	40	—	—	13 13	—	—
8 9	10 3	—	—	0 7	24	—	—	7 14	—	—
8 9	10 3	—	—	0 7	24	—	—	8 1	—	—
16 12	—	—	—	1 0	—	—	—	—	—	—
8 9	—	—	—	0 7	—	—	—	—	—	—
47 4	—	—	—	2 9	—	—	—	48 1½	46 8½	—
29 11	—	—	—	1 12	—	—	—	35 6	38 8	—
22 5	—	—	—	1 5	—	—	—	22 1½	28 4	—
16 12	—	—	—	1 0	—	—	—	17 11	18 10	—
47 4	60 5	—	—	2 9	80	—	—	50 8	65 9	66 3
47 4	60 5	—	47 13	2 9	80	—	2 9	50 8	65 9	66 3
79 4	—	—	79 13	6 12	—	—	6 5	82 0	81 7	—
47 4	60 5	—	47 13	2 9	80	—	2 9	50 8	65 9	—
47 4	60 5	—	47 13	2 9	80	—	2 9	50 8	65 9	—
47 4	60 5	—	47 13	2 9	80	—	2 9	50 8	65 9	—
29 11	37 14	—	—	1 12	60	—	—	44 6	48 11	41 6
29 11	37 14	—	—	1 12	60	—	—	44 6	48 11	41 6
22 5	28 3	—	—	1 5	50	—	—	36 12	36 12	31 6
22 5	28 3	—	22 6	1 5	50	—	1 5	36 12	36 12	31 6
22 5	28 3	—	22 6	1 5	50	—	1 5	36 12	36 12	31 6
22 5	28 3	—	22 6	1 5	50	—	1 5	36 12	36 12	31 6
22 5	28 3	—	—	1 5	50	—	—	36 12	36 12	31 6
22 5	28 3	—	22 6	1 5	50	—	1 5	36 12	36 12	31 6
22 5	28 3	—	22 6	1 5	50	—	1 5	36 12	36 12	31 6
22 5	28 3	—	—	1 5	50	—	—	36 12	36 12	31 6
22 5	28 3	—	—	1 5	50	—	—	36 12	36 12	31 6
22 5	28 3	—	22 6	1 5	50	—	1 5	36 12	36 12	31 6
22 5	28 3	—	22 6	1 5	50	—	1 5	36 12	36 12	31 6
—	—	—	—	—	—	—	—	36 12	—	—
16 12	21 0	—	—	1 0	40	—	—	24 12	25 3	23 8
16 12	21 0	—	—	1 0	40	—	—	24 12	25 3	23 8
16 12	21 0	—	—	1 0	40	—	—	24 12	25 3	23 8
12 10	15 15	—	—	0 12	30	—	—	19 0	18 13	17 12
12 10	15 15	—	—	0 12	30	—	—	19 0	18 13	17 12
8 9	10 3	—	—	0 7	24	—	—	16 15½	12 15	12 4
—	7 12½	—	—	—	18	—	—	13 9	10 12	9 2
79 4	—	—	—	6 12	—	—	—	82 0	—	—
47 4	60 5	—	—	2 9	80	—	—	34 0	—	—
—	—	195 3	—	—	—	10 15	—	—	—	—
—	—	195 3	—	—	—	10 15	—	—	—	—
—	—	87 2	—	—	—	5 4	—	—	—	—
—	—	87 2	—	—	—	5 4	—	—	—	—
—	—	46 1	—	—	—	2 9	—	—	—	—

[1] 100-pr. wrought-iron guns are in the service for coastguard and training ships. Those natures marked with ° are only retained in the service until replaced by rifled guns.

[m] Service cartridges to be of serge; exercising to be of silk cloth.

[n] L.G. is retained for S.B. mortars (see "List of Changes," para. 3760).

[p] For defence of flanks.

PART II.

CHAPTER II.

MANUFACTURE OF R.M.L. GUNS.

General manufacture of R.M.L. guns.—The steel-barrel.—Bending test.—Tensile test.—Tempering in oil.—Water test.—Manufacture of bars and coils.—Welding a coil.—Double coils.—Uniting coils.—Manufacture of a trunnion ring.—Formation of a jacket.—Building up the gun.—Shrinking.—The cascable.—Gas escape channel.—Operations after building up.—Rifling.—Description of the rifling machine.—Splay of the grooves.—Bell mouthing.—Venting.—Different positions of the vent.—The copper bush.—Examination before proof.—Gauging.—Gutta-percha impressions.—Proof rounds.—Water test.—Examination after proof.—Royal monogram.—Weight and preponderance.—Line of metal.—Vertical and horizontal lines.—Lining small guns.—Service venting.—Sighting.—Drilling holes for sight sockets.—Other marks and lines engraved on guns.—Register number.—Heel-scale.—Slot for elevating screw.—Roughing under the breech.—Pivot pieces and elevating plates.—Derricks.—Trunnion studs.—Final examination.—Painting and browning.—Memorandum of examination.

General manufacture of R.M.L. guns.

It will be unnecessary to enter minutely into the manufacture of R.M.L. guns, for both the material and the system on which they were made have been given up in the construction of modern pieces of ordnance; the production of wrought iron has yielded to the manufacture of steel, and with the use of a different material both the forge operations and the method of building up guns have had to be entirely remodelled. It will be sufficient to give a general description of the manufacture of this class of ordnance, taking one gun as a type; afterwards the differences in construction can be pointed out, and some details will be given with regard to each gun, such as their dimensions, sights, fittings, and stores.

Barrel and coils.

All wrought-iron ordnance with very few exceptions consist of a solid-ended steel barrel* supported by coils of wrought-iron successively shrunk over the tube in one, two, or more layers, until the required outline and strength are attained. The trunnion piece, however, has always been forged from a solid block; this was punched into a ring, and generally welded to the exterior breech-coil before being shrunk on to the gun.

7-inch Mark IV as an example.

It will be convenient to take the 7-inch Mark IV for the purpose of illustration, being one of the latest designs among R.M.L. guns. This consists of a barrel, breech-piece, B-coil, B-tube, jacket, and cascable. In explaining the manufacture of these several parts of a 7-inch gun, and the completion of the gun when built up, the descriptions may be

* A few guns of early construction have wrought-iron barrels, and possibly some tubes may be found that have been closed with an "Elswick loose-end." The breech piece also at first was formed out of a solid forged mass, instead of the hollow coil as described in this chapter.

taken to apply (with slight variation) to nearly all other R.M.L. guns, and in some respects also to the manufacture of ordnance at the present time. **CHAP. II.**

The Barrel.

A tube or barrel. The steel block for the A tube or barrel was always supplied by contractors in the form of a solid forged ingot. On receipt in the Royal Gun Factory it was rough-turned for inspection of the exterior, and small discs were cut off at each end from which the test pieces were taken. In this operation a lip also was formed at the muzzle for a clip to take hold of the barrel when being lifted in or out of the tempering furnace and oil-bath.

Test pieces. A set of test pieces consisted of six from each disc, viz.:—three flat bars 4 inches long by $\frac{3}{4}$ inch by $\frac{3}{8}$ inch, and three cylindrical pieces shaped for the testing machine, which were 2 inches long between the shoulders and 0·533 inch in diameter. These were marked S, L, and H in each set, S for *soft* or natural steel, and L and H for those which were to be tempered in oil at a *low* and *high* heat respectively. The heat was judged simply from colour by an experienced workman, "low" heat corresponding to a blood red, and "high" heat to a bright cherry colour.

Bending test. The flat pieces were subjected to a bending test; one end being gripped in a vice, the other was hammered down until the piece was bent double or broke. Soft pieces were expected to bend perfectly double, but they were very often broken afterwards to examine the fracture; the tempered piece H or L which showed greatest toughness would indicate the heat for tempering the barrel.

Tensile test. The round bars were all tested in the machine; the soft material was expected to yield at about 13 tons per square inch, and to break at about 31; the tempered specimens to yield at about 30 and to break at about 48. Elongation was also considered, but no limits were fixed; the general character of the steel determined whether the block should be used or rejected.

Boring. Having passed all the tests for acceptance the block was bored out and tempered. For boring the forged ingot is placed in a lathe, in which the tool is practically stationary (with a very slow onward motion for feed), while the ingot revolves against the cutter. In this way the momentum of the mass is made to assist in the work of cutting out the interior metal. A diameter of a foot has thus been bored out in a single operation, and if a larger hole was required the remainder was removed by a second cut with a tool of a different description.

Tempering in oil. For the operation of tempering, the barrel was placed in a vertical furnace (the bottom resting on supports or a hollow coil), wood only being used for the fuel. When heated to the proper temperature, as indicated by the test piece, it was lifted out by an overhead crane and lowered into a tank of rape oil, where it was allowed to cool slowly. A water space was arranged in the frame of the tank, through which a supply was kept circulating for the purpose of cooling the oil.

Water-test. After tempering, the barrel was again slightly turned and bored out to remove surface cracks, and then it was subjected to a "water-test." For this it was placed horizontally in a hydraulic press, the muzzle end being fitted with a gutta-percha ring and leather cup to render the tube water-tight. It was then filled from the main, and pressure afterwards given by a steam pump. Two indicators were attached, one vertical and one horizontal, so as to check one another, and the pumping was continued until 4 tons per square inch was registered on the pressure gauge. If no flaw was detected by moisture on the exterior, the barrel was considered perfectly sound.

CHAP. II.

Wrought-Iron Coils.

Manufacture of coils.

For the manufacture of coils, iron of superior quality was first produced by means of a puddling furnace; the puddled balls were then hammered into blooms, and the blooms reheated and rolled into slabs. Scrap iron was also worked up into slabs in a similar manner, but of course without passing through fusion; this was a stronger and more fibrous material than that which was produced from cast iron.

Bars.

Slabs were next piled together for the formation of bars, scrap iron being used in the centre, with one slab of puddled iron at top and bottom to give a smooth surface to the bar. The pile of slabs, when reheated to whiteness, was rolled out into a bar from 20 to 30 feet long, varying in thickness from $2\frac{1}{2}$ to 10 inches according to the purpose for which it was made. The section of a bar was trapezoidal, that when coiled on a mandrel with the narrow side inwards, the spreading of the inner and stretching of the out material might bring the folds to a uniform thickness and so make a good helix or coil.*

For the operation of coiling, much longer bars were required, so two and two were scarfed and welded together, and these again were joined up end for end, until the required length was obtained. This generally ranged from 150 to 200 feet, but the longest on record was nearly 300; very long coils were not often employed on account of the difficulty of welding the folds in the middle.

Coiling.

This long bar was prepared for coiling by a scarf at each end, through one of which a hole was punched for a chain to be hooked for the purpose of drawing the bar in or out of the furnace. It was launched into the latter by the help of steam power, and heated to redness on a reverberatory system by fires placed at intervals on either side. When ready for coiling it was drawn out and hooked to a pin on the side of the mandrel; this part had to be cooled down by water to prevent the metal from tearing under the weight of the bar, and then by revolving the mandrel the bar was drawn out and coiled.

Welding the coil.

The next operation was that of welding the coil to unite all the folds of the helix and make a solid cylinder of iron. It was therefore placed upright in a suitable furnace, and brought to a full welding heat, then transferred to an adjacent steam hammer, and a few blows were sufficient for welding; but the operation was always repeated (after another heat) at the opposite end. On each occasion a punch was driven half-way down into the coil, which was then thrown on its side and well hammered all round the exterior; a longer punch might have tended to open the folds which had just been welded together.

Double coils.

Double coils were made by winding a second bar either on this helix or cylinder formed by the first. The welded cylinder naturally gave denser metal inside, and therefore it made a stronger tube for the breech-piece in heavy guns.

Uniting coils.

For extra long cylinders, two coils were united together by a process of rough shrinking and welding, in preference to coiling a sufficiently long bar all at once; the soundness of welding could be better guaranteed in this manner, especially in the middle of the length, where the blow of a steam hammer might otherwise scarcely be felt.

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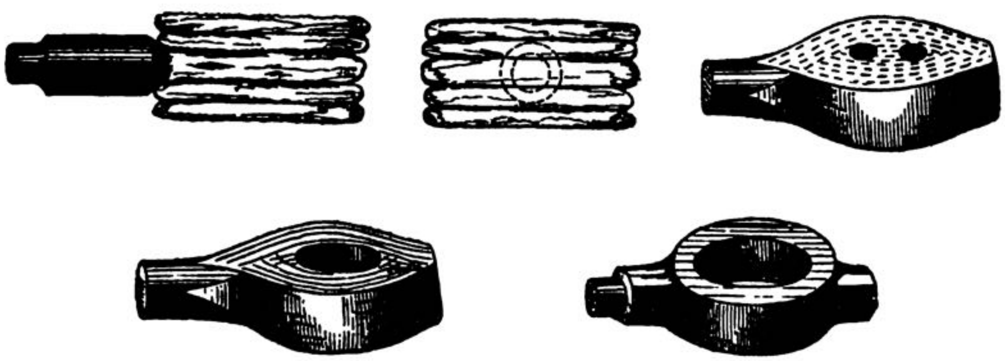
* When bars of greater thickness than 9 or 10 inches were required for coiling they were *forged* into 20 foot lengths, instead of being rolled out from slabs. The nip of the rollers could not always be trusted to effect perfect welding in the middle of so large a bar; and, though more expensive, a denser and stronger material was made in this manner for parts where great strength was required.

Trunnion Rings.

Trunnion ring.

In the formation of a trunnion ring, a solid forging was made on the end of a porter bar, by welding slabs of wrought iron alternately on the upper and lower sides until a sufficient mass was built up. This work was done under a hammer, and the forging was brought roughly to shape. A hole was next punched through the block, and this was enlarged by degrees until a fairly shaped ring was completed; the trunnions were drawn out on each side, and the piece was then cut off from the bar. It will be observed that the fibre in the iron, which in

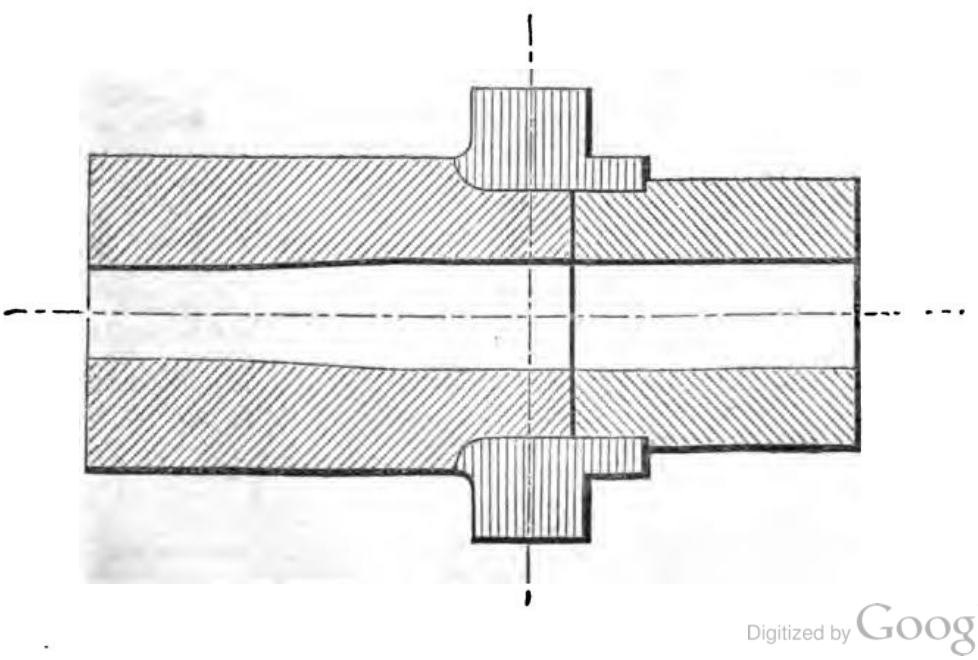


forging would take the direction of length, is thus distributed round the ring without severance, and along each arm of the trunnions; the direction in each case corresponding with the necessity for maximum strength.

The Jacket.

The jacket.

The jacket or outside breech portion was formerly made by welding together two coils and a trunnion ring at one single heat as shown in the figure below; but the smaller coil on the muzzle side was reduced to a mere ring in making a jacket for any of the heaviest guns. The three parts in all cases were first "rough-shrunk" together, the surfaces in contact being previously turned in a lathe. The diameter of the



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trunnion ring when cold was smaller than the diameter of either part over which it would rest, so that after cooling and shrinking there was known to be sufficient metal at the joint to ensure perfect contact and welding. The trunnion ring in this way formed a band over the joint, and the operation of welding the jacket was conducted in much the same manner as that of welding a coil.

Building up.

Building up a gun.

Shrinking has always been resorted to for building up guns, not only as an easy and efficient method of binding successive parts firmly together, but also for regulating the tension of each layer so that all the metal may contribute in fair proportion to the strength of the piece.

Shrinking.

When any two parts are about to be put together by shrinking, the interior surface of the outer portion is first completely finished in a lathe. This is gauged, and a plan is drawn out with the measurements reading to a thousandth of an inch. If there is any difference or taper the change must be regular, and the smallest diameter must be at the upper end with regard to its position when being put on the gun. A second plan is then made for the exterior dimensions of the inner piece, in which the measurements are larger than the corresponding parts of the first plan by the amount which is to be given for "shrinkage;" the

surface of this piece is then turned down and finished with emery powder to these larger dimensions.

The operation of shrinking is simple; the outer coil is expanded by heat until sufficiently large to fit easily over the inner. A wood fire on bars under a crane is generally used, and the coil or tube itself forms a flue.* When raised to blue heat the coil is lifted from the fire, and the inside being thoroughly cleaned it is dropped over the part of the barrel or gun (set vertically in a pit) which has been prepared to receive it. The heat required is not very great, for the linear expansion of iron between 32° and 212° Fahr. has been determined by several authorities at 0·00122 of its length, so the co-efficient of expansion for every degree is about 0·000007. Roughly speaking, we may calculate that the diameter of a coil of wrought iron would be increased to the extent of one-thousandth by the addition of 150 degrees of heat. Some 600° or 800° are therefore sufficient for the operation of shrinking; but this temporary expansion by heat must not be confounded with the permanent extension which is left in the coil by this method of building with shrinkage.

When cooling, great care is required to prevent a long tube from taking a grip at both ends while the middle remains in expansion. The shoulder of bearing must always come first into contact, and all the mass must cool slowly and shrink towards the end at which contraction

* Gas is used in some cases. It is immaterial how the heat is applied, so long as it is uniformly distributed and the manner of application is not injurious to the metal. A wood fire in the open under a crane is generally found most convenient.

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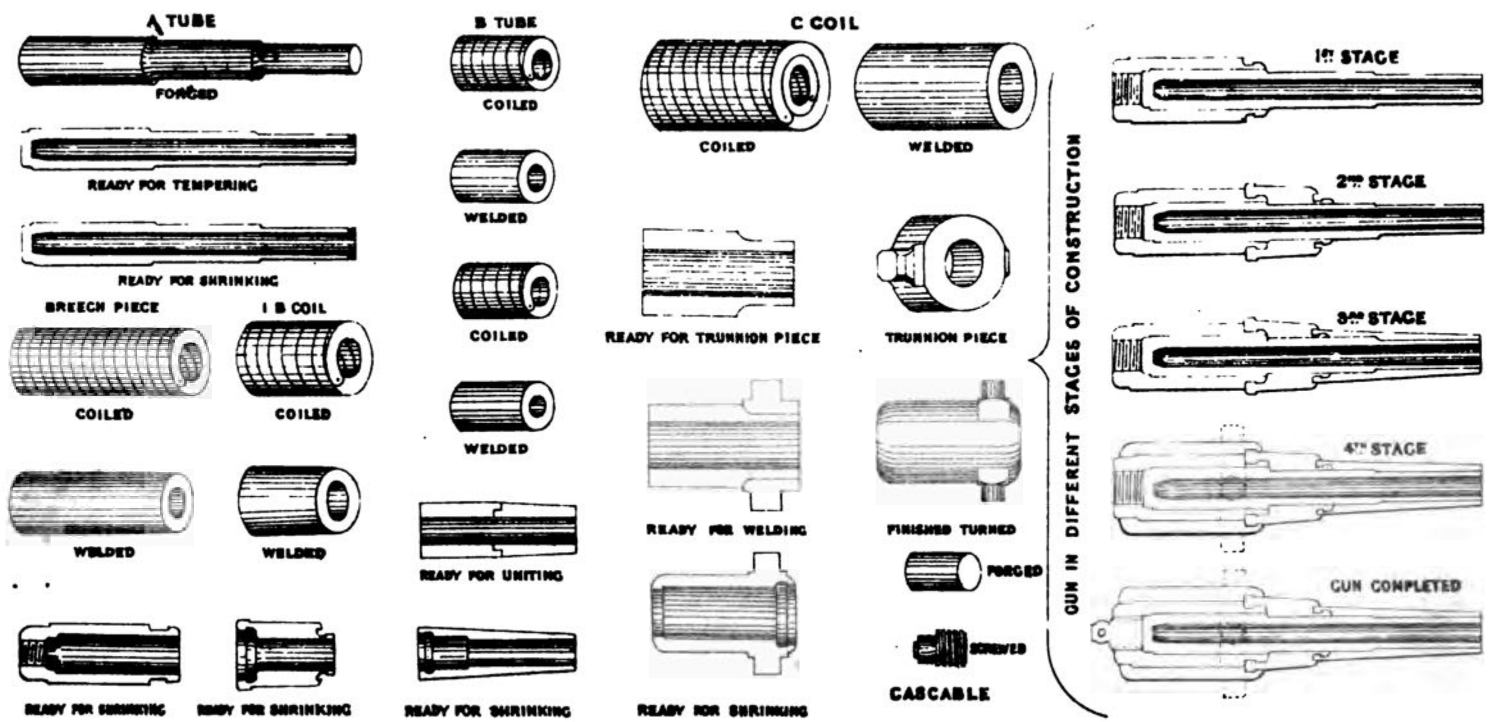
DIAGRAM

ILLUSTRATING THE VARIOUS STAGES OF MANUFACTURE OF A 7 INCH 7 TONS GUN MARK IV.



is allowed to commence. Water is generally applied to the part where first contact is wanted, and gas jets are often arranged in rings round the rest of the tube, which can be put out in succession as the process of cooling goes on. The inside of the gun is always kept cool, to hasten the work and promote regular contraction commencing from the inside of the coil.

Cascable.

When the whole gun had been built up in this manner* a cascable was screwed into the breech to support the end of the barrel. This was forged solid, turned down into shape, and provided with a strong bevel thread; a hole was also drilled in the rough end, for the purpose of screwing it into the gun, which was afterwards enlarged into the cascable loop. In fitting a cascable it was necessary to exercise care that the front should bear evenly against the end of the barrel; to ascertain that this was the case the end of the tube was smeared with red-lead while the cascable was screwed in for trial. When unscrewed and taken out for inspection the red-lead should be equally diffused on the face of the block; if discovered in patches these spots would indicate the prominent parts, which had to be filed, and the operation of fitting was repeated until a satisfactory result was obtained.

Gas Escape Channel.

Operations after building up.

At this stage the cascable was once more withdrawn and the last thread was turned off from the end of the screw, so that, when placed in the gun an annular space was left all round the end of the barrel. From this a cross-channel was cut longitudinally on the right side† of the block $\frac{1}{10}$th of an inch deeper than the bottom of the threads of the

screw, forming the gas-escape hole which is seen at the breech. This is intended to act as a tell-tale in case the steel barrel should split, and the passage must be kept clear in action, though it may be temporarily plugged with grease and tow, to prevent it from getting stopped up with dirt.

When the mechanical fit was accomplished and the channel correctly prepared, the cascable was finally screwed in with great force, and a plug was inserted through the breech-piece (which entered about half-an-inch into the cascable) to prevent its getting loose after adjustment.

* At one time the cascable was screwed into the breech before the jacket was shrunk on, under an idea that the grip of the jacket helped to secure the screw in its threads; but the heat was liable to cause some expansion, and this might be followed by irregular contraction, in which case the mechanical fit and good bearing would be destroyed.

† In guns made before September, 1869, the channel was placed *under* the cascable; but since that date on the right side, where it may be more easily noticed.

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Operations after Building-up.

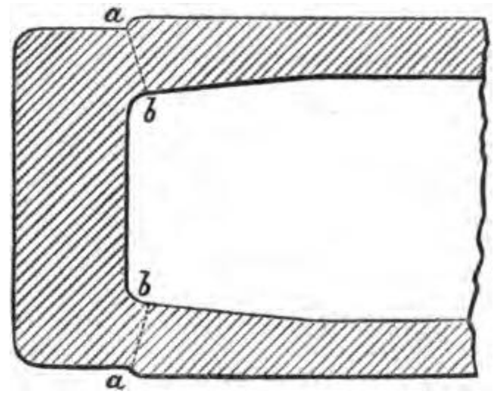
We may now suppose that all parts of the gun have been put together and that the outline has also been given; for in the process of building, the gun has had to return to the lathe after each portion was placed in position. We come next to the various operations for completing an R.M.L. gun, many of which are exactly the same for all kinds of ordnance, including the breech-loading guns which are now being made.

Fine and finish boring.

Lapping.

Coned end of the bore.

Internally the gun is bored up to calibre by successive operations of fine boring, finished boring, broaching, and lapping. A coned end was given to the bottom of the bore in most heavy R.M.L. guns; but this was not done with the view of making a "chamber" in the present sense of the word; it was "coned" only for strength so as to leave sufficient thickness of metal to make good a reduction on the outside of the



barrel, as shown in the figure, which was cut away to form a shoulder to take the longitudinal thrust.

Rifling.

The next operation is "rifling." For this the gun has to be placed horizontally in a machine; each groove is cut singly, the form of groove being given by the shape of the cutter; but the depth is gradually attained by slow feeding of the tool after each stroke. When one groove is finished the gun has to be turned on its axis to another position, and the next groove is cut in a similar manner. The distance between the grooves may be obtained by means of a disc on the breech or a ring over the chase, divided on the periphery into as many equal parts as there are to be grooves in the gun.

The Rifling Machine.

Rifling machine.

In this machine the gun remains stationary while the rifling bar, carrying the cutter, works horizontally in and out of the bore; great care must be taken in placing the gun that the bar may be perfectly true with the axis. The gun-metal head in which the cutter is fixed is made to fit accurately in the bore by means of burnishers; it is fastened to the end of the rifling bar, which is hollow, and a rod passing down the centre of the latter regulates the feed of the cutter.

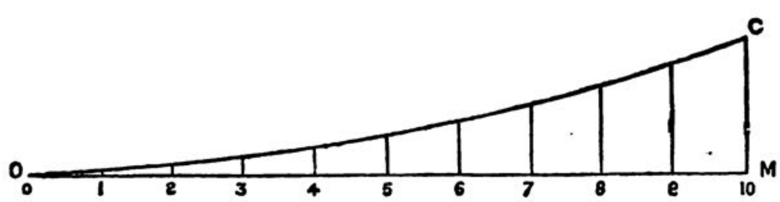
The horizontal motion of the bar is derived from an endless screw in the bed of the machine by means of a saddle, which is made to travel on two fixed slides; a reversing arrangement (which acts automatically) is added to regulate the length of the stroke. In machines of an early type the reversing is effected by the use of two mitre-wheels gearing into a bevelled wheel on the end of the screw on opposite sides; one mitre-wheel is attached to its pulley by means of a short hollow

spindle, and through this a solid axle can work, which connects the other pulley with the mitre-wheel on the opposite side; an idle pulley is placed in the middle, which is attached to no axle at all. When the band from the shafting is pushed on to one or other of this set of pulleys, either the rifling bar can be made to travel in the direction required or the machine can be brought to rest. The automatic arrangement consists in a set of levers, which push or pull the leather strap from one working pulley to the other. A long rod is carried down one side of the machine, and on it a stop is secured near each end for a collar (which projects from the saddle) to catch against and so work the lever; on its coming into contact the bar is pulled by the onward motion of the saddle, the band is shifted to the opposite pulley, and the direction of motiom is reversed. The same action takes place when the collar comes in contact with the stop at the other end; so the motion is regularly changed when the cutter reaches a definite point in the bore, and again at another point just outside the muzzle. A hand lever is also provided for a workman to start or stop the machine.

Quick-return motion. With the use of mitre-wheels it is evident that as much time is required for the cutter to travel when idle as when it is doing its work. A "quick-return" motion is now given to most of the machines, by which there is much saving of time. This is generally effected by employing two sets of pulleys of different diameters on a prolongation of the screw-shaft itself; a strap for each set is required, one of which must be twisted or crossed to give motion in the contrary direction to the other. Only the outside pulley in each set is a working one, all the others being necessarily idle, and the rate of driving the screw can be made to vary with the different size of the pulleys.

Twisting motion. To give a twist to the groove it is necessary that the rifling bar should turn round on its axis at the same time that it moves in and out of the gun. The amount of this turning round on it axis will determine the spiral described in the bore. To effect this a rack is placed in the saddle, which gears into a toothed band on the bar; the rack works between guides, which compel it to travel at right angles to the direction of the bar; it is pushed or pulled across the saddle by means of two friction rollers which have to follow the edges of a copying bar, and thus the rifling bar is turned round on its axis. With uniform twist the amount will depend on the angle at which the copying bar is attached to the machine, or any curve may be given to the latter and this curve will be strictly reproduced in the groove. By changing the copying bar one machine will suffice for any description of rifling, and also for different guns, provided the right length of stroke can be given.

Copying bar. The formulæ for construction of copying bars have already been given; with ordinary conic parabola $y = \frac{\pi b^2}{2nl}$



As an example, suppose that $n = 35$ and $l = 100$ inches. Then $y = \frac{\pi}{70}\left(\frac{b}{10}\right)^2$. Now let b have all values from 0 to 100 as closely

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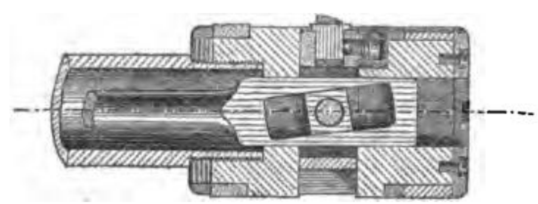
as may be required, say 10, 20, 30, &c., and let $\frac{\pi}{70}$ be represented by c; then $y = c$, $4c$, $9c$, &c.; so the curve OC may be drawn.

The cutter.

The cutter is made of very hard steel, set firmly in the middle of the rifling head in a carrier or slide, which is capable of moving in a slot at right angles to the axis of the rifling bar. The movement of the slide is effected by means of a square-headed spindle, the head of which works in an inclined slot near the end of the solid bar, which passes down the whole length of the hollow one. On pulling this bar the square-head must adjust itself in the slot, and so force the cutter towards or away from the surface. The action of bringing the cutter into play and of withdrawing it within the recess is regulated by an automatic arrangement on the opposite side of the machine to that on which the copying bar is attached. This consists of two level surfaces, along which a weighted lever can travel backwards and forwards, while the short arm of the lever is able to act on the feed bar. When the rifling-head is passing *into* the gun the weighted



RIFLING HEAD.

lever moves on the upper surface, and in its raised position it pushes the feed bar, and the cutter is drawn into the recess. When the motion of the machine is reversed the lever is prevented from returning along the same level by means of a tripper, then by falling to the lower surface it gives a pull to the feed bar and the cutter forced out to its work. The weighted lever now travels along this lower level, and at the other end of the machine (just at the time when the motion is reversed) it is compelled to ascend to the upper surface again, and so draws the cutter into the head. The cutter is fed out more and more after each stroke by regulating the position of the feed bar, one end of which is secured in the saddle; on this end a screw-collar is fixed, and after each stroke a small turn is given to a hand-screw on the top, by which means the feed bar is drawn back and a different part of the slot is brought into action; each small turn of the hand-screw in direction of feed sufficiently alters the cutter until the full depth of groove is attained, and this point must be carefully watched by the constant application of a gauge.

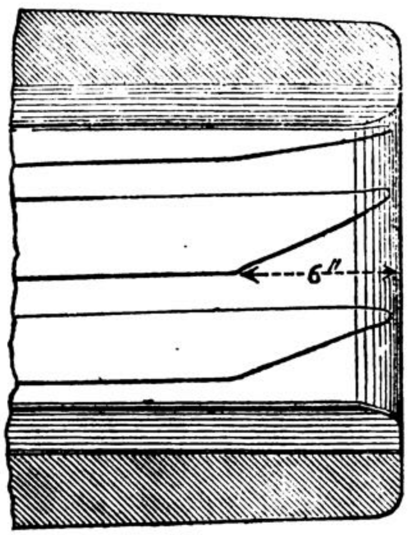
Splay and Bell-Mouthing.

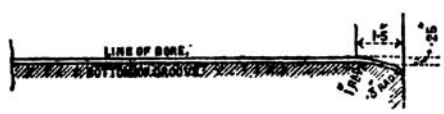
Splay of grooves.

The 6·6-inch, 10-inch, and all larger natures of R.M.L. guns have the loading side of the groove cut away at the muzzle, with the object of facilitating the operation of loading. The extent of splay differs, but a full splay may be said to remove almost the whole of the lands near the muzzle, so that the studs may enter the bore in whatever position the projectile should happen to be raised; on pressing the shot into the gun,

the studs follow the edge of the splay and bring the shot into position for being rammed down the bore. Without splay it would be necessary to have the projectile raised exactly in the right position for loading, or else it would be necessary to turn the shot round in its sling; in either case the loading would require much more attention and time.

SPLAYING OF GROOVES FOR GUNS OF 10-INCH AND UPWARDS.





Section showing Bell-Mouthing of Bore.

All 10-inch and upwards are also "bell-mouthed" at the muzzle; that is to say, the metal round the entrance to the bore is filed away to the extent of a quarter of an inch, the slope is then carried to a distance of one inch and a half down the bore, and the sharp angles are further removed especially on the face of the muzzle. The bell-mouth has been added, like the splay of the grooves, to facilitate the operation of loading, but it also relieves the strain on the barrel when the shot is just leaving the muzzle, and so tends to prevent a crack starting in that part of the tube. Bell-mouth.

Venting

With very few exceptions all R.M.L. guns are vented through the middle of a copper bush set radially in the upper part of the breech of the gun. Field and siege ordnance which are liable to be fired with reduced charges, are generally "rear-vented," that is to say, at the extremity of the bore; there is a notion, too, that by igniting the charge at the end all residue and smouldering matter would be driven out of the gun. Venting.

From experiments in 1863 it appeared that the best ballistic results were obtained when the cartridge was ignited almost at the middle. It was therefore decided that heavy guns should be bushed in a "forward" position, and a rule was established that the vent should strike the cartridge at a distance of $\frac{4}{10}$ths of its length from the end of the bore. Position of vent.

Some medium guns which were rear-vented at first have since been re-vented with a bush in forward position, the old hole being plugged up with steel. A gain of velocity was brought about by this change, with greater uniformity of pressure in the gun: wave-action was also diminished, and with it a cause for premature explosion of shell.

Chambered guns.

Chambered guns, such as the 13-pr. and others, are exceptions to the foregoing rule, for these are vented in the middle of the chamber: if reduced charges should ever be fired they ought to be made up to full length. The 12·5-inch Mark II and all heavier guns are fitted with axial vents, so they form an exceptional class. A description of the axial vent will be found in the next chapter among the fittings and stores for these guns. *Vide* also p. 206.

Copper vent-bush.

The vent-bush is a cylinder of hardened copper $1\frac{1}{8}$ inches in diameter, with a screw thread $\frac{1}{16}$ inch deep, having a pitch of seven threads to the inch. The length varies for thickness of metal in the gun. At one end a square head is provided for screwing the bush into position; at the other the cylinder terminates in the frustrum of a cone $1\frac{1}{4}$ inches in length and $\frac{7}{8}$ inch in diameter at the smallest part.

For 9-inch guns and upwards the thread is limited to a length of 6 inches from the top of the cone, the upper part of the bush being smooth, for this amount of screw thread has proved quite sufficient to hold the vent-bush in its place.

Vent-channel.

The vent-channel is 0·22 inch in diameter for guns of every description, but the mouth is rimed out for sea service to suit the quill friction tubes to a diameter of 0·28, the taper extending to the depth of an inch.

Special bush.

The bush of the 7-pr. gun is exceptional, both in size and screw thread, having 18 threads to the inch, and being only 0·625 inch in diameter.

Proof vent.

For proof, steel bush was always fitted to a gun the cone of which was slightly smaller than that on a bush of service dimensions; this bush was afterwards exchanged, the cone being rimed out, and any risk of the copper being set up by proof was in this manner avoided.

Examination before Proof.

Examination by gauging and G.P. impressions.

All guns are most carefully examined after leaving the workshops before being subjected to proof. The bore is gauged to a thousandth of an inch, both vertically and horizontally, at points 3 inches distant all the way down. Gutta-percha impressions are taken of the whole length of the bore in four quarters; also separate impressions of the chamber when of larger diameter than the bore, and of the region of the vent or of the end of the bore when required.

Proof rounds.

Proof rounds are next fired from the gun. These differ in their proportion to the service charge according to the nature of piece:—the smaller R.M.L. guns were all proved by firing two rounds with a charge $1\frac{1}{4}$ the amount intended for service, and a solid cylinder of the same weight as the service projectile.

For heavier guns, viz., 8-inch and upwards, the proof consisted of one service round, being the battering charge assigned to the gun, and two rounds of proof charges which were either $1\frac{1}{4}$ the previous amount or such other quantity as might be laid down for each particular nature. Special charges were necessary when the cartridge became excessively long, for a small increase of powder will then sometimes give a considerable increase of pressure. Accordingly for 9-inch and heavier guns the following scale was drawn out for proof:—

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			Battering charge.			Proof charge.
9-inch	.. ..	..	50 lb. P.	..	..	58 lb. P.
10 „	.. ..	..	70 „	..	..	75 „
11 „ 12 „	} 25 tons	..	85 „	..	..	95 „
12 „	.. 35 tons	..	110 „	..	..	115 „
12·5 „	Mark I	..	160 lb. P² $\frac{30 \cdot 0}{0 \cdot 924}$		..	180 lb. P² $\frac{30 \cdot 0}{0 \cdot 924}$
12·5 „	Mark II	..	210 lb. Prism¹ $\frac{30 \cdot 1}{0 \cdot 921}$			225 lb. Prism¹ $\frac{29 \cdot 0}{0 \cdot 956}$

There is a double object in testing a gun with these charges, for not only does the proof guarantee that the gun is strong enough for the ammunition on service, but it settles the shrinkage and tension in all parts of the gun.

Water test. After firing guns are further tested by water pressure in the bore, to the extent of 120 lb. on the square inch. This test was first instituted for guns with wrought-iron barrels having various forms of loose end, to ascertain that the breech was perfectly closed; it was afterwards continued with solid-ended steel barrels to make sure that the end had not split.

Examination after proof. When these tests are satisfactorily passed, a gun is carefully examined again. Sometimes the shrinkage is so great that the measurements after proof show contraction in the bore; expansion to any great extent would be an indication of weakness. Again, the coils may contract longitudinally, and this at the muzzle will cause an appearance as if the barrel had shifted; ccntinued firing on service may also have this effect. Gutta-perchai mpressions are taken once more, and these are compared with the first set; if a defect has been developed, or if any mark previously noted has perceptibly increased, the gun is further subjected to five service rounds and the examination repeated until the gun is either passed or condemned. The impressions of any defects (which are generally tool marks) are preserved for reference if necessary at any future time.

Operations after Proof.

After proof. After proof the bore is lapped out once more to remove any scratches or burrs which might have been caused by the firing.

Royal monogram. The Royal monogram is stencilled in outline upon the correct part of the gun, and afterwards engraved by hand labour.

Weight. The piece is weighed, and the weight is stamped on the breech. A strong steel-yard is used for this purpose which is capable of weighing 25 tons; if the gun, however, is heavier than this, the jacket and other finished portions must be weighed separately before they are shrunk up together. All heavy guns are new generally weighed in two or three parts.

Preponderance. The preponderance is taken by means of a Kitchener's weighing machine. For this the gun is supported at the trunnions resting on steel plates or bars, and its axis is brought horizontal by a handspike in the bore while a spirit level is placed on the breech. In this position it is scotched up on the weighing machine by a block under the breech placed at, or midway between, the points of attachment of the elevating gear.*

Line of metal. The line of metal is now marked on the gun. This is the basis of all sighting arrangements, and is generally obtained in the following manner:—

The gun is placed on a perfectly level and smooth iron table, cross-

* Lines showing the position of the centre of gravity and half weight are marked on most 8-inch guns and upwards by this means.

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levelled itself over the trunnions and in the bore. To find the line of metal alone it is not essential that the axis of the bore should be quite horizontal, but for other lines which are usually found at the same time this adjustment is necessary. The first step then is to place a silk cord in the exact centre of the bore at the breech and the muzzle to represent the axis of the piece; this thread is carried on to a standard a few yards in front of the gun, and another line is obtained in the same vertical plane sufficiently high to rest on the top of the breech. To find the position of the axis a centering block is passed down the bore which exactly fits the calibre of the gun, and the cord is attached to the centre of this block. At the muzzle a plate is secured which has a small hole in the centre for the cord to pass through; this plate must be accurately set with a level, and the cord brought to the exact centre of the hole by means of horizontal and vertical pointers. The axis line is extended some yards to the front of the gun, where the thread is made fast to a moveable vertical standard, which must be carefully plumbed. The thread is then carried upwards in the same vertical plane to a higher part of the standard, and thence back through the plate on the muzzle to a "breech-gauge" on the gun. By adjustment in the plate at the muzzle the cord is there brought vertically over the lower thread; consequently the two threads are in the same vertical plane throughout, and at the point where the cord is made fast at the breech it is vertically over the axis. This gives the position for the line of metal, which is marked on the cylindrical part of the breech by a line about 2 inches long.

Vertical and horizontal lines.

Vertical and horizontal lines are then marked with a scriber on the face of the muzzle along the edge of slots cut in the plate; horizontal lines are also marked with a scriber (which is set to the thread at the muzzle and tested by the lines on each side) on both sides of the muzzle and breech for the purpose of adjusting the fittings; for these lines of course it is necessary that the gun should have been previously levelled in the bore.

On the right trunnion both vertical and horizontal lines are engraved in the case of 40-pr. and all heavier guns. The vertical line may be used to lay the gun "point-blank" with a plummet, and the horizontal line may prove useful for giving elevation with a clinometer or when firing at angles of depression.

Lining small guns.

With small guns that can be turned over by hand on the table, there is a more simple method for finding these lines. When the gun has been carefully cross levelled, a plate is attached to the muzzle which must also be levelled before it is clamped. A scriber is then set to the upper edge of a slot in the plate, which must of course be true for both sides, and with this the horizontal lines are marked on the muzzle and breech. When the gun is turned round through a quarter of a circle so as to bring the axis of the trunnions in a vertical position, the same process is repeated, and the line of metal is then marked on the gun.

Service venting.

The proof-vent is now exchanged for a service bush, to receive which the cone in the gun has to be slightly rimed out. When the copper bush is firmly screwed in, a gutta-percha impression is taken of the part that projects into the bore; having marked the *direction of the muzzle* on the head of the bush, it is taken out of the gun and inserted in the same position as before in the gutta-percha impression, so that a line may be scribed round the cone corresponding to the surface of the bore. The end of the bush is then filed to what is technically called a "button-head," so as to fit perfectly in the gun round the edge, while the centre is left full to a thickness of about 0·075 inch. When the inside is satisfactorily finished, as shown by another gutta-percha impression,

the surplus metal at the top is sawn off about one-fifth of an inch above the surface of the gun; the copper is freely trimmed off outside the bush and in the vent channel, and the rest of the metal is then hammered down to set it into the threads and prevent the bush from becoming unscrewed. The channel must afterwards be rimed out to gauge, and for sea service the mouth is enlarged with a vent-rimer which is supplied for this purpose.

Sighting. Sighting is one of the next operations, and this requires very great accuracy and care. Small guns have fore-sights screwed into the piece; the adjustment of these is exactly the same in the first instance as in a case of repair, except that sighting instruments are used in the workshops, and that holes must be first drilled in the gun. A description of the method of repairing these sights in the field, with the tests for adjustment, will be found in Part IV of this work.

The 25-pr. R.M.L. gun and all heavier natures have removable sights, and the adjustment is then made in the sockets which are let into holes in the gun.

Drilling holes for sight sockets. When drilling the holes for sight-sockets the gun is placed horizontally under a radial drilling machine, and as the tool is perpendicular to the arm, and the hind-sights are required to be set at an angle of permanent correction for drift, the gun is turned round in a contrary direction to the angle of sighting till the trunnions are inclined at that angle. A breech gauge and muzzle plate having been correctly attached to the piece, silk threads in pairs are stretched from one to the other, between which the drill must perform all its work without cutting either of the threads: the right and left pairs are placed on the gauge equidistant from the centre, but in consequence of turning the gun on its axis through the angle for correction of drift, the position of the holes on the gun with regard to the line of metal is not equidistant when the trunnions are brought horizontal. The distance of the holes from the breech gauge is determined by a steel bar, and the arm of the machine is brought over each spot in succession without altering the position of the gun. The holes for the fore-sights are drilled in a similar manner, but the axis of the trunnions is then placed horizontal. Their position is found from the radial distance assigned to the sights, measured parallel to the axis of the piece. The thin edge of each hole or recess is rounded off to prevent injury when shifting and moving the gun.

The sockets are fitted by hand with dummy sights, and they are made of gun-metal to obtain a perfect adjustment: when accurately fitted they are secured by fixing screws.

Other marks on a gun. In addition to the lines mentioned already as engraved on a gun, the broad arrow and actual weight are engraved in front of the vent; and since 1875 the angle of correction for drift has also been stamped on the breech.

On 9-inch and heavier guns, up to the 12-inch of 25 tons, a letter D should be found in front of the centre-hind-sight, which has been placed on all guns whose sockets have been deepened to receive the lengthened sight.

Two lines are cut across the upper surface of the breech to indicate the unrifled part of the bore: the one shows the end of the rifling, and the other the end of the bore.

Similar cross lines are cut on 64-pr. and all heavier guns to show the position of the centre of gravity, and on the 8-inch and upwards, the point of "half-weight"; the latter being over that part of the chase where one of the slings should be placed when the other is under the cascable, in order that the gun may be raised horizontally.

The material of the A-tube is stamped on the face of the muzzle;

and a number also which only refers to its registration in the books of the Royal Gun Factory.

Register number.

On the left trunnion will be found (1) the name or initials of the factory or firm where the gun was manufactured; (2) the registered number of the piece; (3) the numeral which indicates pattern; and (4) the year in which it was made. The numbers run consecutively

through all guns of one nature, and do not recommence with each mark. It is most important that this number should be stated correctly in all returns and reports, for it may be the only means of identifying the gun in the War Office records.

Heel-scale.

A "heel-scale" was formerly engraved on the cascable for all the S.S. guns for which wood-scales are provided. The graduations on this scale refer to a radius distance on the axis of the piece from the centre of the trunnions to the rear face of the cascable, where the scale is engraved. It usually reads to about $3\frac{1}{2}$ degrees above and below zero.

Slot for elevating screw.

In 25-prs. and all smaller natures, the cascable is slotted underneath to receive the head of the elevating screw.

Roughing the breech.

Heavy guns were formerly scored under the breech on each side, with the object of preventing the handspikes from slipping when applied for giving elevation. This was no longer required when elevating racks were adopted. On a few guns in the service these marks may be found now on the upper side of the breech, because the guns have been "turned over," revented, and the fittings readjusted.

Pivot pieces.

Pivot pieces and elevating plates are attached to each piece according to the method of mounting: also index plates on heavy guns and the guide plate, friction tube pin, &c., for sea service. The position for each fitting is carefully ascertained by means of a template or gauge from the lines marked on the gun: screw holes are bored and tapped for these fittings, which when properly attached are stamped with the number of the gun to which they have thus been adjusted.

Derricks and muzzle studs.

9-inch guns and upwards are now always prepared for muzzle derricks. 7, 8, and 9-inch R.M.L. guns were formerly furnished with two studs in the face of the muzzle to support the shot bearer. In 1871 these studs were abolished, and preserving screws should be placed in their stead.

Trunnion studs.

Trunnion studs have been fitted to R.M.L. guns of 38 tons weight and upwards, as a great convenience for mounting, especially in casemates when using the box-girder frame.

Final examination.

When a gun is completed with all sights, fittings, &c., it is finally examined, and painted or browned before issue to the Commissary-General of Ordnance. 25-pr. guns and all larger natures are painted with Pulford's magnetic paint, and the bore is coated with lacquer; smaller guns for L.S. are browned on the exterior and the bore is left clean and bright, but for sea-service all guns are painted without respect to their size.

Paint and browning.

A Memorandum of Examination is delivered with every gun to the

Memorandum of examination.

Commissary-General of Ordnance, which contains a description of the piece and a drawing to show its construction, dimensions, &c.; on the first page are noted any marks or apparent defects to guide an examiner at a future inspection, and all subsequent repairs in the Arsenal are entered here for a similar reason. On the second page a diary is prepared to show the whole history or life of the gun; every round should be registered whether fired with a projectile or blank. Inside sheets to keep up this register can be obtained on application to the Superintendent of the Royal Gun Factory. A few general instructions are added on the 3rd or 4th page, which may prove useful to the officer in charge of the gun.* When the piece is handed over from one charge to another, or returned into store, this Memorandum of Examination must invariably accompany the gun, and be mentioned on the receipt and delivery vouchers.

* The form of a Memorandum of Examination is given at the end of Part IV, p. 371. Inside sheets can now be obtained from the Ordnance Store Department.

PART II.

CHAPTER III.

SIGHTS, FITTINGS, AND STORES FOR R.M.L. ORDNANCE.

Sighting of Ordnance.—Centre and side-sighted guns.—Principle of service sighting.—Forces acting on a projectile in air.—Effect of gravity.—Resistance of the atmosphere.—Drift.—Method of determining the angle of correction for drift. —Jump.—Shot's trajectory.—Sight-points on a gun.—Rough and fine laying.

Service sights.—Fore-sights.—Muzzle-sights.—Trunnion-sights; Screw and drop pattern.—Centre-fore-sights.—Hind or tangent sights.—The Burton instrument for engraving tangent scales.—Graduations marked on hind-sights.—Long and short radius.—Deflection leaf.—Centre-hind-sights.—Lengthened pattern.—Centre-hind-sights for 12 and 12·5-inch guns.—Table of latest marks of all tangent and centre-hind-sights.

Special sights.—Index plates.—Elevating arcs.—Wood scales.—Table of wood scales for S.S. guns.—Clinometers.—Quadrants.—Graduated arcs on metal racers. —Hanging scales.—Cross-bar sights.—Turret sights.—Compound turret sights.—Reflecting sights.—Chase sights.—Sights for Moncrieff carriages, Marks I and II.—Special sights for 6·6-inch and 100-ton R.M.L. guns.

Fittings and small stores.—Shot bearers.—Slinging cascable.—Counter-balance. —Cradle.—Derricks.—Extractor.—Guide plate.—Hand rifling machine.—Friction tube pin.—Pivot pieces.—Prickers.—Set-screws.—Spanners.—Spikes.—Trunnion studs.—Wrenches.—Shutter.—Axial vent.—Table of sights, fittings, and stores for each nature of R.M.L. gun.

Before entering into the details which will have to be pointed out concerning each nature of gun, it will be advisable to describe generally the systems of sighting and other means which have been provided for laying ordnance, so that these arrangements may be clearly understood when mentioned hereafter in connection with any of the guns.

Service sights. The service sights consist of one, two, or three sets, a set being generally two sights, one fixed and the other adjustable; but a third sight may be found in one or two cases as part of the set.

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Centre and side-sighted guns.

Small guns as a rule have only one set, and these are placed on the line of metal or top of the gun; such guns are said to be "centre-sighted." Medium pieces are provided with two sets, a pair being affixed to each side, and these may be called "side-sighted" guns; the side position was adopted for greater convenience in laying, while a second set affords the advantage of maintaining the gun fit for action after one sight has been irretrievably damaged.

64-pr. R.M.L. guns and all heavier natures as a rule are both side and centre-sighted, the centre-sights having been added to meet the contingency of firing at a moving object when the gun is traversed to the full extent of the embrasure. and the object is approaching from the side to which the muzzle of the gun is directed; in such a case the line over that side might be obscured by the parapet, while the other sights would be of no use, for the muzzle itself would hide the object from view.

Forces acting upon the projectile in air.

To understand the principle of laying a gun and the peculiar methods of attaching the sights, one must consider the forces at work on a projectile after leaving the bore. These are gravity, resistance in the air, and some force or condition of motion which deflects the shot from a straight path.

Effect of gravity.

Gravity tends to bring down the projectile to earth, but this may be counteracted by throwing the shot upwards, that is to say, by giving elevation to the gun, taking care to direct the axis to the same height above the object, as the force of gravity would draw it down in the time required for flight. Practically the amount of elevation for range is determined by firing the gun at different degrees of inclination, and measuring the distance of impact or graze on perfectly level ground.

Resistance in the atmosphere.

Resistance in the atmosphere retards the motion of projectiles, and consequently affects both range and time. Its effect is felt in the vertical as well as the horizontal components of motion, but not to the same extent, retardation being in proportion approximately to the cube of the velocity and area of the surface which is offered to resistance. With a low trajectory and high initial velocity in the shot the vertical component may generally be neglected. Retardation of projectiles has already been discussed as fully as the limits of this book will permit, but the effect of atmospheric resistance on range may be clearly exhibited by taking any example:—*e.g.*

The 13-pr. R.M.L. gun with a M.V. of 1,595 f.s. will in in 5·3 seconds of time give a range of about 2,000 yards: in vacuo the distance traversed with the same initial velocity and in the same time would be 2,818 yards, which shows a loss of range due to resistance of air of about $\frac{2}{7}$ths of the distance in space. This proportion will vary of course with different natures of guns, or rather with different projectiles and their respective initial velocities, but it is always a considerable amount.

As regards the effect on height of a trajectory, we are unable to make a similar comparison, for the force of gravity has only been determined in air. The expression $4\,t^2$ will give the maximum height in feet (approximately), but this is obtained from the general formula $\frac{1}{2}\,g\left(\frac{t}{2}\right)^2$ for half the time of flight, and it involves taking the force of gravity at the value assigned to it near the surface of the earth.

Drift.

We come next to the deflection of a shot from the vertical plane in which the axis of the gun is directed. This is termed the "drift" of the projectile. The causes of drift are mysterious and very complex, so that no definite explanation can be given; it may be due to gyration of the shot, or to unequal pressure or friction on the surface when

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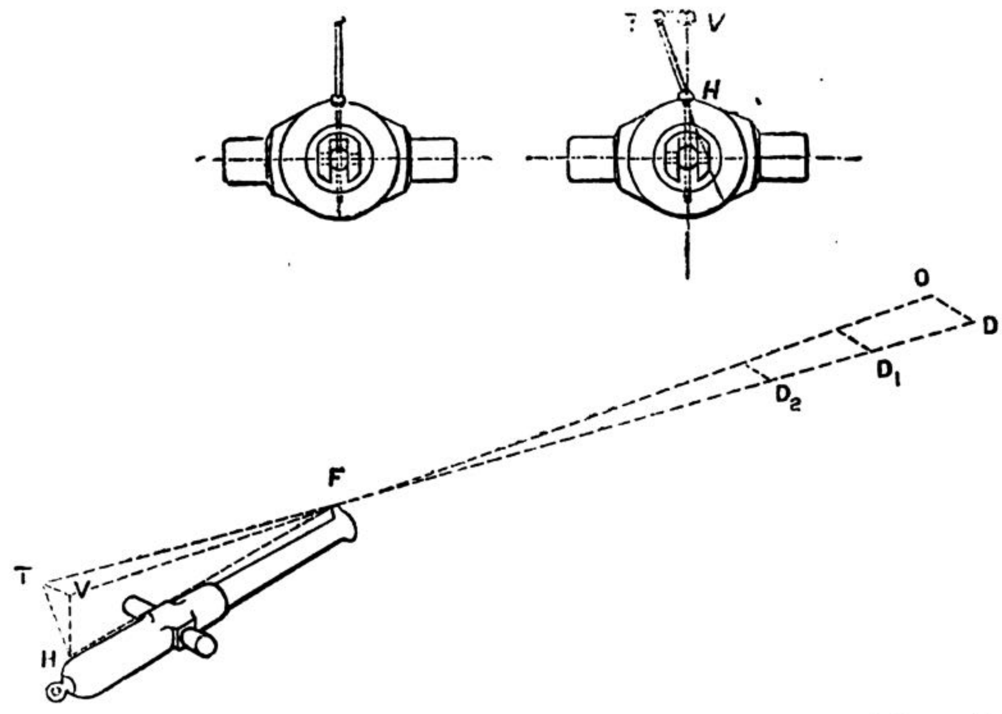
spinning in the air;* but whatever the cause, it is known that with right-handed twist of the rifling a pointed projectile will drift to the right, and with left-handed twist it will drift to the left. The amount of deflection is also irregular and cannot be reduced to a law, depending upon the form, weight, velocity, and spin of the projectile; this point has therefore to be practically determined for every nature of gun.

Determination of drift.

The method adopted is by firing at Shoeburyness. Several series of rounds are fired on a still day at different elevations, say 1°, 3°, 5°, 7°, &c., the gun being always laid on the same line, and the elevation being given by a quadrant. The shot will fall in groups to the right of the line, and the mean distance of each group is taken as the deflection for that range which must evidently be attributed to drift. These points may not lie in a perfectly straight line or furnish a constant angle of deviation from the straight line, but they will indicate the general shooting of the gun, and a mean angle of correction can be worked out from these data, at which the hind-sight should be set in the gun, so as to direct the axis to the left of the object by an amount which shall always bear the propor proportion to range.

The calculation may be explained by the aid of a figure: let HV represent a hind-sight raised vertically for giving elevation, say ϵ; let F be the fore-sight, and let VF be directed on an object at O. The mean deviation for each group of shots for different values of ϵ may be shown by the points D, D_1, D_2, &c. Take the measured distance OD as equal to *d*, when the range FO = R; join DF and produce it to T;



then join TV and TH, taking care that the line TV is at right angles to VF and in the same horizontal plane.

Then T is the point at which the head of the hind-sight ought to be

* A spinning teetotum will drift in the direction of spin, and a cylindrical body revolving on its axis will roll to one side if dropped on a hard surface like earth; in the same way we can readily suppose that an elongated projectile spinning in contact with compressed atmosphere underneath, would have a tendency to drift in the direction of revolution of the shot.

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placed to throw the axis of the gun sufficiently oblique with the line of sight for the shot to strike the object at O instead of falling at D. Then the angle VHT or δ may be found in the following manner:—

By similar triangles TV : VF : : DO : OF : : d : R.
But TV = HV tan VHT; and VF = HV cosec ϵ.

So tan VHT or tan $\delta = \frac{d}{R}$ cosec ϵ.

The value of δ should be worked out for each range, and the mean taken as the angle of correction for drift.

Jump.

There is yet one other correction which cannot be altogether ignored when calculating the yard-scale which is generally inscribed on the sights; this is commonly known as the "jump."

It is practically found that the muzzle is almost always thrown upwards on firing to the extent of some minutes of elevation or perhaps even half a degree, before the shot has left the bore of the gun. This angle of increased elevation or jump seems mainly to depend on the carriage or system of mounting, for in some carriages of modern construction it has been found that the muzzle may be *depressed*, and the jump therefore have a negative value. Whatever its value may be, it must directly affect elevation, and a correction has to be made in the range table, especially for high-velocity guns. The amount of jump must be determined by practice.

Trajectory.

From these remarks it will be understood that the path of a projectile in air does not follow any straight line, but the trajectory lies in the midst of several lines which may be drawn from the muzzle, or sights on a gun; to facilitate the work of laying a piece with service sights, the line of sight is made adjustable to the axis, so as to eliminate as far as possible all calculation in practice.

Sight points.

Two points outside the gun are required to give this adjustable line, and these points are known as the "sights." The fore-sight, which is usually fixed, gives one point at a certain distance from the axis of the piece; the hind-sight is placed in a socket at the correct inclination to a vertical plane, with an arrrangement for clamping it at any height, so as to give elevation and eliminate automatically the constant correction for dritt. Force of wind and speed in the object must of course be computed on every occasion, and other means are provided for meeting these variable conditions of fire.

Deflection.

All hind-sights for rifled ordnance, with very few exceptions, are fitted with a sliding leaf, which carries the notch through which the line of sight is to be taken. This leaf is graduated with a scale for deflection right and left of the zero point, and when set in position it must be clamped by a thumb-screw; in modern sights this arrangement has been improved by the adoption of a traversing-screw, which dispenses with the necessity for a clamp. Barrel-headed sights are also used in which deflection may be given by turning a mill-headed-screw on the head to the right or the left.

Depth of notch.

The depth of the notch was formerly 0·06 inch for land service, and the sights were adjusted for the line to be taken through the *bottom* of the notch. For S.S. this was afterwards deepened to 0·15 inch, but the adjustment of the line of sight was unchanged. The deeper notch was subsequently adopted for all heavy guns, *i.e.*, for the 64-pr. and upwards, for the sake of uniformity of pattern. In 1882 a question was raised at Shoeburyness as to the relative merits of taking a fine or full sight; opinion decided in favour of the latter as being less tiring to the eye, and therefore conducive to accurate shooting, especially in continuous fire. With this object, and to meet the conditions laid down in the Manual of Artillery Exercises, it was then ordered that all L.S. guns

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should in future be sighted for a "full-sight"; so the line connecting the apex of the fore-sight and the *top* of the notch is now made parallel to the axis of the piece.

Service Sights.

Service sights.

Various descriptions of sights are supplied with different natures of ordnance, which may be generally classed as service or special sights. A similarity in principle runs through all those of service pattern, and naturally they claim first attention.

Service sights are divided into fore-sights and hind-sights; there are several varieties of each, but they are not interchangeable one with another.

Fore-Sights.

Fore-sights.

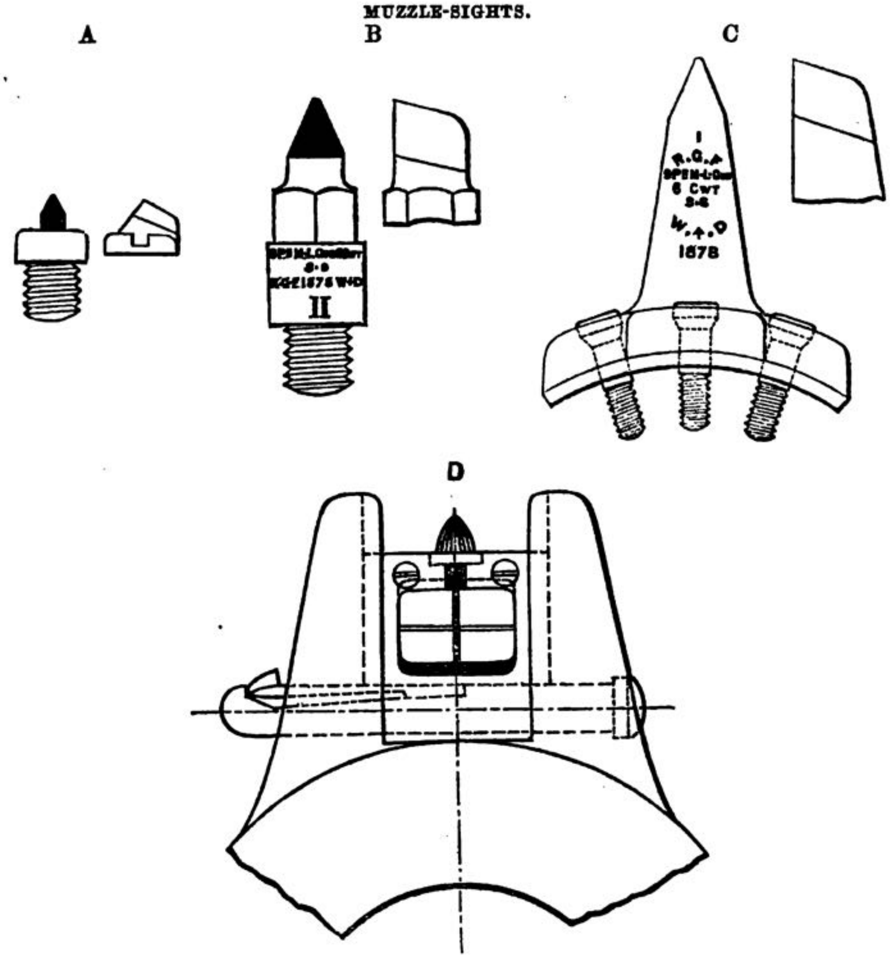
The term "fore-sight" embraces all those which are known as muzzle, trunnion, and centre-fore-sights. These names refer to their position on the gun.

Muzzle-Sights.

Muzzle-sights.

Muzzle-sights will be found of four patterns, viz.:—

MUZZLE-SIGHTS.



(A) Small hog-backed sights, which are screwed into a recess in the muzzle on 9-pr. land service guns, and on the 64-pr. of 58 cwt.

(B) Pillar-sights, which are screwed into the surface of the muzzle on

7-pr. guns of 200 lb., and 9-pr. S.S. guns of 8 cwt., Mark II, and 6 cwt., Mark III; the height being required to make up for the absence of a swell at the muzzle, and to raise the line of sight above all the fittings of the breech.

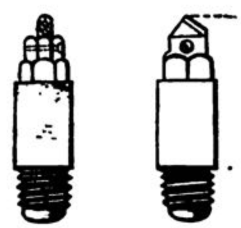
(C) Block-sights, which are attached to the muzzle of 9-pr. S.S. guns 6-cwt., Mark I, by three fixing screws: and

(D) Window-sights, for rough and fine laying, such as are fitted to the 13-pr. R.M.L. gun, which drop into a dispart patch on the muzzle, and are secured in position by a keep-pin with a spring ring. An acorn is fixed on the top to be used in connection with an ordinary notch on the hind-sight, and cross-wires are placed in the window below for fine laying through a small eye-hole which is situated below the notch in the hind-sight.

When these sights are not required for use they should be removed from the gun for safe keeping, and preserving blocks should be put in their place.

Trunnion Sights.

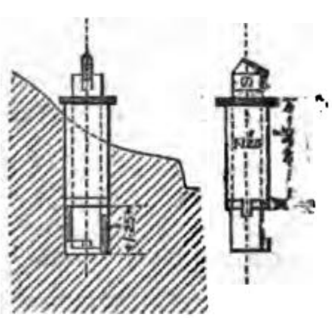
Trunnion sights. Trunnion sights may be of two kinds, either screwed in the gun or removable with a bayonet joint. When screwed in they are pillars of steel with a rough leaf at the top, which must be filed to a hog-backed



shape so as to fulfil the conditions of adjustment, *after* being fixed on the gun. When damaged it will be generally sufficient to exchange the leaf. As it is difficult to regulate the tapping of a screw thread so as to bring the leaf parallel to the axis of the gun these sights require careful adjustment, and they must always be used in the positions to which they have been fitted. Screw trunnion sights are now only used with the 16-pr. R.M.L. gun and the lighter natures of R.B.L. guns.

The removable kind are termed "drop-sights," because they can be kept safely in store and readily dropped into their sockets when required for use.

Drop sights. A drop-sight consists of a pillar and collar of gun-metal with a small steel leaf at the top, and a screw for fixing the leaf. The socket also



is made of gun-metal permanently fixed in the gun, and adjusted by means of a "gauge-sight." The drop-sight is secured in its socket by

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a double bayonet joint. To remove it the collar must be raised and the pillar turned round a quarter of a circle; when fixing, the operation is simply reversed. These sights are interchangeable for all guns of the nature to which they belong, but as the leaf is fitted and tested on a particular gun before issue, the sights and sockets are stamped with corresponding numbers and also with the number of the gun that they may always be used if possible in their right place.

Centre-Fore-Sights.

Centre-fore-sights.

Centre-fore-sights are always made of the "drop" pattern, but they are usually shorter than the sights at the side; consequently they are not interchangeable with the latter, or available for other natures of guns than those which are specified on them.

Hind-Sights.

Hind-sights.

Hind-sights are either called "tangent" or "centre-hind" sights, according to their position on a gun; they are all tangent sights by graduation, only the term centre-hind-sight was adopted to distinguish those which were made of a special pattern, and graduated for a different radius distance.

Tangent-sight.

The name "tangent-sight" is derived from the fact that the *length* of the bar for any given elevation on the gun must always be equal to the tangent of that angle with a radius equivalent to the distance between the two sights.

The length of a tangent-sight may be found from the formula $T = r \tan \epsilon$. The length for each degree must be found independently, because the value of the tangent increases more rapidly than the angle itself; even the subdivisions of a degree are calculated also when the radius distance is sufficiently long, but otherwise the small readings are obtained by division.

Burton instrument.

An ingenious machine was invented by a foreman named Burton in the Royal Gun Factory, for engraving the scales on a tangent-sight bar. A copying cylinder or cam was first made for each nature of gun; when fixed in the machine this governs the progress of the bar under the cutter, by means of a pin fixed so as to work in the grooves of the cam which are cut at the exact distance apart required for the divisions on the scale; the face of the bar is made to reciprocate under the cutter once for each revolution of the cam, and so the scale is engraved without a chance of mistake, and every bar must be exactly alike.

Tangent-sights have passed through many changes of pattern, but the present form may be generally described as a rectangular steel bar, ~~rounded off on two sides, and fitted~~ with a gun-metal head, in which the ~~deflection leaf~~ can be ~~adjusted and clamped~~.

For land service a slow motion screw was added to the head of the bar in the 16, 25, 40, and Mark III 64-pr. R.M.L. guns for giving elevation to a *minute;* but this will not be found on any other sights except those for the 12·5-inch L.S. gun with which this arrangement has been revived.*

Scales on tangent-sights.

The tangent scale is engraved, as a rule, on the front of the bar, and it is well to bear in mind that this is the only permanent scale on the sight; all others are liable to change with any variation in charge, &c. A range scale in yards, deduced from special practice, is engraved on

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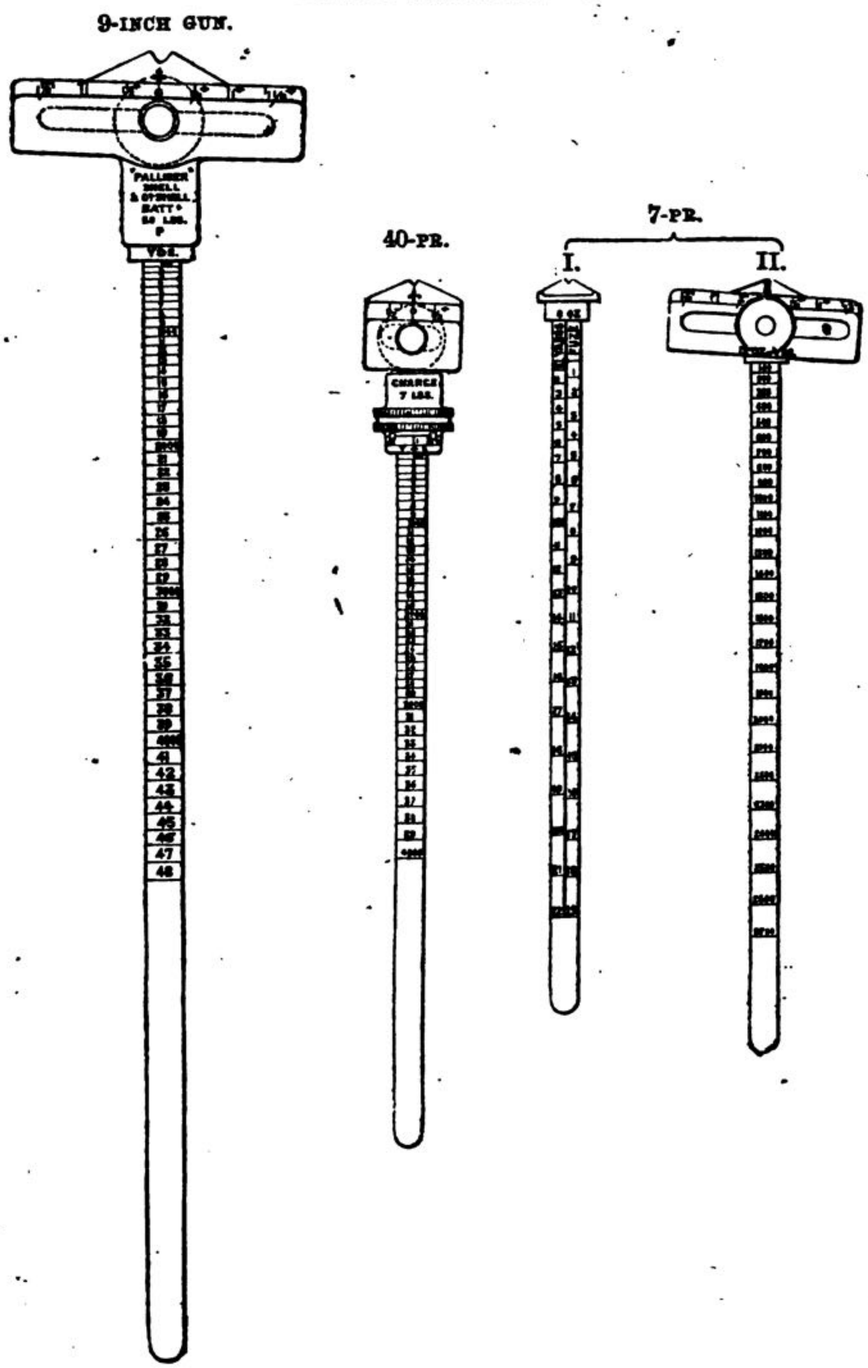
* A few have also been made for 35-ton R.M.L. guns for L.S., but most of the guns of this nature are mounted in turrets on board-ship, and are therefore provided with other systems of sighting. In the 2·5-inch gun this arrangement has been applied to the clamp.

the hind face, and on one side will be found the corresponding length required for the fuze. Yards and fuze scales are given as far as possible for the different charges and projectiles used with the gun, but these scales must depend on uniformity in the conditions of firing; any change in the quality of the powder, in the density of the charge, or in the weight of the projectile, &c., will cause a change in the muzzle velocity, which will affect the shooting of the gun if simply laid by the estimated distance in yards.

TYPES OF TANGENT SCALES.



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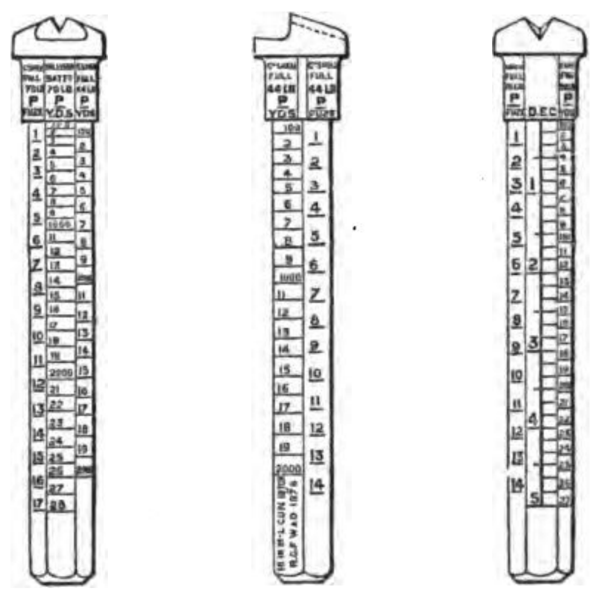
Long and short tangent-sights. Two tangent-sights of different lengths are supplied with each 7, 9, and 13-pr. R.M.L. gun. The shorter one only may be carried in the gun; for higher elevation than the maximum given on this scale the longer sight must be taken instead; it is too long to be kept in the gun, for the projecting part underneath would be liable to get bent or damaged.

Deflection leaf. The deflection leaf on all sights was formerly graduated to give 80 minutes deflection right and left, but this has proved to be insufficient. Additional deflection has now been given to most heavy guns to the full extent that alteration of the sights could be easily made; the extension was effected by increasing the length of the slot in the gun-metal head, so as to allow a greater travel to the leaf. The amount of deflection on the latest pattern sights for R.M.L. guns may be found in § 3963; it is also given in Table XVIII (see page 148).

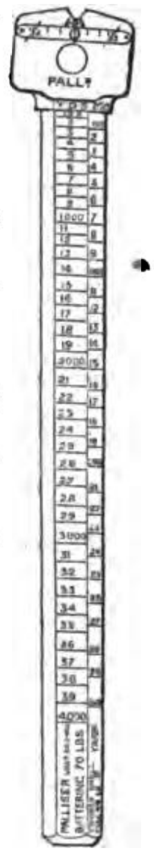
Centre-Hind-Sights.

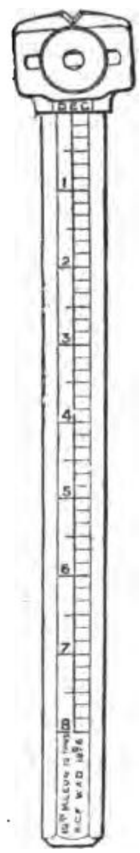
Centre-hind-sights. All centre-hind-sights were originally hexagonal bars of gun-metal, without deflection leaf, and they differed in pattern for land and sea service. They were graduated only for 5° of elevation, and the yard and fuze scales for different charges were engraved on the several faces.



Lengthened C.H. sight. In 1874 a longer sight with deflection leaf was prepared for all heavy guns of 9-inch calibre up to 12-inch of 25 tons. These sights were not necessarily supplied, but it was ordered that the sockets should be deepened in all cases, so that the guns would be prepared to receive them. Instructions were sent out for this work to be performed by local artificers,* and the letter D should be stamped in front of the socket to show that the work has been done.

* See page 382.





For 12-inch of 35 tons and 12·5-inch Marks I and II, the centre-hind-sight for L.S. is precisely the same as the side-sight, and the radius distance is exactly the same. The centre-sights are usually set at a greater radius distance than the side sights, and the hexagonal form may be due to a precaution which was taken to render it impossible to use any of these sights in the wrong place.

C.H. sights for 12 and 12·5-inch guns.

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TABLE XVIII.

Showing latest Mark of all Tangent and Centre-Hind-Sights for R.M.L. Guns.

Gun.	Angle of correction for drift.	Radius distance.	Latest Mark of Sight.*	Reference.§	Graduations. Degrees.	Range Scale. Charge.	Range Scale. Projectiles.†	Range Scale. Yards.	Fuse, tenths.	Deflection, Right and Left.	Remarks.
	° ′	inches.				lb.				° ′	
17·72-inch— Tangent	1 20	60	I	4372	8	...	...	...	...	1 30	Special.
16-inch— Tangent	...	...	...	4079	...	...	...	...	...	3 0	
12·5-inch, Mark I— Tangent	2 10	72	I	3119	10	...	...	...	...	0 30	
12·5-inch, Mark II— Tangent	2 10	72	I	4080	10	...	...	...	...	0 30	
12-inch, 35 tons— Tangent	1 25	72	I	...	10	{ 85 P. { 100 P.	C P	4,500 4,800	20 ...	} 0 30	Not sealed.
12-inch, 25 tons— Tangent	0 30	54	III	3963	12	{ 55 P. { 85 P.	P or C P or C	4,000 4,800	24 32	} 0 40	
Centre-hind	0 30	59·95	III	2701	10½	{ 55 P. { 85 P.	C P	4,000 4,800	... ...	} 0 30	
11-inch— Tangent	2 26	54	II	3963	12	{ 60 P. { 85 P.	C P	4,500 4,800	20 ...	} 0 40	
Centre-hind	2 26	59·95	II	2701	10½	{ 60 P. { 85 P.	C P	4,000 4,800	... ...	} ● 30	
10-inch— Tangent	1 10	54	III	3963	12	{ 44 P. { 70 P.	C P C	4,000 4,800	30 34	} 0 40	
Centre-hind	1 10	60	III	2701	8	{ 44 P. { 70 P.	C P	3,000 4,000	... ...	} 0 30	
9-inch— Tangent	0 44	45	IV	3963	15	{ 30 L.G. { 50 P.	C P	4,000 4,800	27 32	} 0 45	
Centre-hind	0 44	45·1	V	2701	7½	{ 30 L.G. { 50 P.	C P	3,100 3,700	... ...	} 0 30	
8-inch— Tangent	0 28	38	III	3963	15	{ 20 L.G. { 35 P.	C P C	4,000 -4,800	30 33	} 0 50	
Centre-hind	0 28	38·1	III	2198	5	{ 20 L.G. { 35 P.	C P C	2,300 2,500	15 15	} ...	
7-inch, 6½ and 7 tons— Tangent	3 0	38	IV	3963	15	{ 14 L.G. { 30 P.	C P C	4,000 4,800	30 27	} 0 50	
Centre-hind	3 0	38·1	III	2198	5	{ 14 L.G. { 14 L.G. { 30 P.	D C P C	1,200 2,200 3,000	8 15 19	} ...	
7-inch, 90 cwt.— Tangent	0 44	38	III	3963	15	{ 22 P. { 14 L.G.	P S C C	4,000 4,000	27 20	} 0 50	
Centre-hind	0 44	38·05	I	3685	5	{ 22 P. { 14 L.G. { 22 P.	D C P S C	2,000 2,200 2,300	... 15 16	} ...	

* The description of earlier patterns of sights may generally be traced in the "Changes of War Stores," by reference to the § quoted.

N.B.—By an Order dated W.O. 21–12–76, all sights passing through the Department and altered, but not brought up to any sealed pattern, are to have the numeral of the Mark to which they are assimilated stamped after the numeral for their original Mark; thus, I (IV).

† C Common Shell,
S Shrapnel ,,
D Double ,,
P Palliser Shot or Shell.

TABLE XVIII—*continued.*

Guns.	Angle of correction for drift.	Radius distance	Latest Mark of Sight.*	Reference.§	Graduations.					Deflection, Right and Left.	Remarks.
					Degrees.	Range Scale.			Fuse, tenths.		
						Charge.	Projectiles.†	Yards.			
	' °	inches.				lb.				° '	
6·6-inch—											
Tangent scale ...	1 30	34·4		4373	10	...	...	...	...	1 30	This scale has a reflector fixed to head, in rear of deflection scale.
64-pr., Marks I and II—											
Tangent	2 16	38	VII	3963	15	8 R.L.G. 10 R.L.G.	C C	3,600 5,000	27 34	0 50	
Centre-hind	2 16	38·1	V	2993	5	8 R.L.G. 10 R.L.G.	C C	2,000 2,500	13 16	...	
64-pr., Mark III—											
Tangent	2 50	38	VII	2993 3963	15	10 R.L.G. 8 R.L.G.	... ...	5,000 3,600	... ...	0 50	
Centre-hind	2 50	38·1	V	2993	5	8 R.L.G. 10 R.L.G.	C C	2,000 2,500	13 16	...	
80-pr.—											
Tangent	0 19	38	II	3963	15	10 L.G.	C	3,500	20	0 50	
64-pr., 71 cwt.—											
Tangent	2 16	38	IV	2198	15	8 L.G.	C	3,600	27	0 30	
64-pr., 58 cwt.—											
Tangent‡	2 16	38	VI	2993	12	8 L.G.	C	4,000	31	1 30	
40-pr., 34 cwt.—											
Tangent	1 20	30	I	4119	12	7 R.L.G.	C S	4,000	26	0 30	
40-pr., 35 cwt.											
Tangent	1 20	36	II	4119	12	7 R.L.G.	C S	4,500	30	0 30	
25-pr.—											
Tangent	0 53	30	I	3204	12	4 R.L.G.	C S	4,000	20	0 30	
16-pr.—											
Tangent	1 50	24	I	2221 4181	12	3 R.L.G.[2]	C S	4,000	28	0 30	
13-pr.—											
Tangent ... Short ...	1 30	85·2	I	4067	5	3¼ R.L.G.[2]	C S	2,800	18	1 0	
Tangent ... Long ...	1 30	85·2	I	4181	12			4,800	30	1 0	
9-pr., 8 cwt., Mark I—											
Tangent ... Short ...	1 30	66	II	2352 2636 4181	6	1¾ R.L.G.[2]	C S	2,400	16	0 30	
Tangent ... Long ...	1 30	66	II	2352 2636 4181	12			3,500	20	0 30	
9-pr., 8 cwt., Mark II—											
Tangent ... Short ..	1 30	65	II	4378	6	1¾ R.L.G.[2]	C S	2,600	16	1 30	
Tangent ... Long ...	1 30	65	II	4378	12			3,500	24	1 30	
9-pr., 6-cwt., Mark I—											
Tangent ... Short ...	1 30	54·6	II	...	7	1½ R.L.G.[2]	C S	2,400	15	1 30	
Tangent ... Long ..	1 30	54·6	II	...	12			3,300	20	1 30	
9-pr., 6 cwt., Mark II—											
Tangent ... Short ...	1 30	68	III	3071	6	1¾ R.L.G.[2]	C S	2,100	12	0 30	
Tangent ... Long ...	1 30	58	III	4181	12			3,500	20	0 30	

* The description of earlier patterns of sights may generally be traced in the "Changes of War Stores," by reference to the § quoted.

N.B.—By an Order dated W.O. 21-12-76, all sights passing through the Department and altered, but not brought up to any sealed pattern, are to have the numeral of the Mark to which they are assimilated stamped after the numeral, their original Mark; thus, I (IV).

† C Common Shell.
S Shrapnel ,,
D Double ,,
P Palliser Shot or Shell.

‡ This tangent sight resembles a centre-hind-sight in being an hexagonal gun-metal bar.

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TABLE XVIII—*continued.*

Gun.	Angle of correction for drift.	Radius distance.	Latest Mark of Sight.*	Reference.§	Graduations. Degrees.	Range Scale. Charge.	Range Scale. Projectiles.†	Range Scale. Yards.	Fuze, tenths.	Deflection, Right and Left.	Remarks.
	° ′	inches.				lb.				° ′	
9-pr., 6 cwt., Mark III—											
Tangent... Short ...	1 30	67·5	II	4378	7	1¾ R.L.G.[2]	C S	200 to 2,400	12	1 30	
Tangent... Long ...	1 30	67·5	II	4378	12	1¾ R.L.G.[2]	C S	200 to 3,300	20	1 30	
7-pr. Bronze, 200 lb., Mark II ...	3 0	33·5	I	1935	5	8 oz. F.G.	...	...	...	...	S.S. only.
			I	...	17	...	D S C S	700 to 1,200 1,700 to 2,800	9 to 17 14 to 26	...	Wooden scale.
7-pr. Steel, 150 lb., Mark III—											
Tangent... Short ...	3 0	24.2	II	1717	10	4 oz. F.G. 6 oz. F.G.	... ...	600 1,500	9 14	...	This is a wooden scale.
Tangent... Long ...	3 0	24·2	II	1811	20	4 oz. F.G. 6 oz. F.G.	... ...	1,100 2,000	17 21	...	
7-pr. Steel, 200 lb., Mark IV—											
Tangent... Short ...	3 0	36·4	II	4378	8	12 oz. F.G.	...	2,000	15	1 30	
Tangent... Long ...	3 0	36·4	II	4378	12	4 oz. F.G. 12 oz. F.G.	... ...	700 to 950 2,700	8·5 to 12·5 23	1 30	

* The description of earlier patterns of sights may generally be traced in the "Changes of War Stores," by reference to the § quoted.

N.B.—By an Order dated W.O. 21-12-76, all sights passing through the Department and altered, but not brought up to any sealed pattern, are to have the numeral of the Mark to which they are assimilated stamped after the numeral of their original Mark; thus, I (IV).

† C Common Shell.
S Shrapnel "
D Double "
P Palliser Shot or Shell.

SPECIAL SIGHTS.

Special sights.

Besides the ordinary sights which are generally supplied with every gun, there are many special arrangements for laying ordnance to suit different conditions of mounting. These may be divided into three groups, viz.:—

(1) For giving elevation only:—
 Index plates and elevating arcs.
 Wood scales.
 Clinometers.
 Quadrants.

(2) For giving direction only:—
 Graduated arcs.
 Hanging scales.
 Cross-bar sights.
 Turret sights.

(3) Reflecting sights:—
 Chase sights.
 Mirror sights for Moncrieff Carriage, Mark I.
 " " " Mark II.
 Special sights for the 6·6-inch and 100-ton R.M.L. guns.

We proceed to give a short description of each of these stores, with a few remarks to explain the method of using them.

Index Plates, and Elevating Arcs.

Index plates. §§ 3226, 3787.

Index plates have been fitted to all R.M.L. guns from 9-inch to 12-inch of 25 tons, when mounted in casemates or behind iron shields. The plates are issued in pairs for the right and left sides of the gun, being simply gun-metal arcs secured to the breech by two fixing screws. The arcs are graduated for 10 degrees of elevation, and for 6 degrees of depression. They must be fixed on the gun at a correct radius distance from the axis of the trunnions. Screw holes are prepared for these plates before the guns are issued to service.

A "reader" or bracket of gun-metal is attached to the carriage exactly opposite the face of the plate, which shows by its straight edge against the scale the angle of inclination of the piece. The reader must correspond with the zero on the scale when the axis of the gun is horizontal.

There are two patterns for 9 and 10-inch R.M.L. guns, to suit different carriages. Mark II for 9-inch is used with the single plate carriage, and Mark II for 10-inch with the "low" carriage. These patterns, however, differ merely in the slightest details. They are all stamped with the nature of gun for which they are respectively suited.

Elevating arcs.

For S.S. the elevating arcs are generally graduated, and these scales are used in conjunction with pointers fixed on the clamp brackets.

Wood Scales.

Wood scales.

Wood scales are supplied only for naval service; they are used in connection with the ship's pendulum or director. There are three patterns: (1) for converted R.M.L. guns, having a shoulder to mark the zero point on the scale; (2) flat bars for R.B.L.

CHAP. III. guns what are called "*wood side-scales,*" because they are applied to the side instead of the end of the gun; and (3) square bars for R.M.L. guns with a scale on each face, viz.: a degree scale and range scale in yards for full, battering, and reduced charges; this pattern is provided with a moveable slide, which is fitted with a pointer and clamp for greater convenience of use.

Adjustment. The wood scales are issued longer than necessary, that a piece may be cut off the bottom to adjust them to any particular carriage. The adjustmont should be made when the slide or carriage is trained on the beam, and the gun run out to firing position; the axis of the piece must be brought parallel to the athwarthship plane of the racer, and the wood scace is then cut so that the elevation is shown to be zero.

Mode of use. The mode of use is as follows:—When the slide has been clamped at the required elevation or estimated range, the pointer is applied to the heel scale engraved on the rear face of the cascable; if the ship is on even keel the gun must be elevated until the pointer corresponds with the zero; but if the vessel is heeling towards or away from the object, the angle of heel must be found from the director, and the pointer will then be applied at the same angle marked on the heel scale above or below zero, as indicated by the words "To" and "From."

The extent of graduation may differ in the wood scales for the same nature of gun, for these stores have been frequently made for special carriages on board different classes of ships.

The wood scales which are used with guns mounted on muzzle-pivoting carriages have an arrangement by which they can be lengthened or shortened when necessary.

A table of all the latest marks of wood scales for R.M.L. guns is given below:—

TABLE XIX.

WOOD SCALES FOR R.M.L. ORDNANCE.

Gun.	Latest Mark.	Graduations.	Reference. §	Remarks.
64-pr., 71 cwt. ...	I	6° D to 12° E.[a]	1,752	[a] This is a side scale for guns mounted on wooden carriages. [b] For guns mounted on iron carriages.
64-pr., 64 cwt. ..	II	8° D. to 13° E.[b] Shell, 6 lb., yards, 3,600 " 8 " " 4,000 " 10 " " 5,000	3,012 3,684	
7-inch, 90 cwt.	II	7° D. to 22° E. Shell, full, 14 lb., yards, 4,000 Double shell battering, yards, 2,500 Battering, 22 lb., yards, 4,000	3,683	
7 inch, 6½ tons	IV	7° D. to 22° E. S. or S. full, 14 lb., yards. 1,500 D. S. full, 14 lb., yards, 1,200 S. or S. battering, 30 lb. P., yards, 3,000	—	
8-inch	II	7° D. to 22° E. S. or S. full, 20 lb., yards 2,000 S. or S. battering, 35 lb. P., yards, 2,500	—	
9-inch	III	7° D. to 22° E. S. or S. full, 30 lb., yards, 2,000 S. or S. battering, 50 lb. P., yards, 3000	—	
10-inch	II	7° D. to 12° E. S. or S. full, 44 lb., yards, 2,000 C. S. battering, 70 lb. P., yards, 3,000 S. or S. battering, 70 lb. P., yards, 3,000	—	
11-inch	I	6° D. to 10° E. C. S. full, 60 lb. P., yards, 4,000 S. or S. battering, 85 lb. P., yards, 4,800	3,153	* Special for each ship according to mode in which guns are mounted.
12-inch, 25 tons	*	—	—	
12-inch, 35 tons	*	—	—	
12·5-inch, 38 tons, Mark I	*	—		

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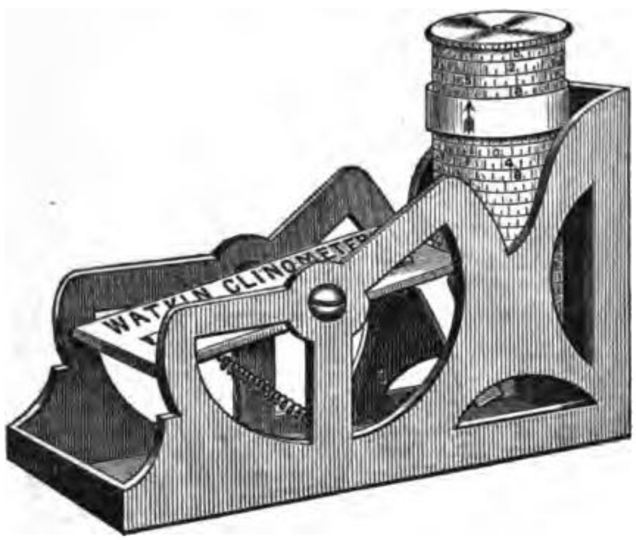
Clinometers and Quadrants.

Two kinds of clinometer have been introduced in the service which are issued as part of the equipment for field and siege guns, viz.: the boxwood and Watkin clinometers. **Clinometers.**

The boxwood clinometer is a 12-inch rule with a quadrant joint in the middle, and a spirit level set in one edge. This can be applied to a gun in the bore, on the top of the breech, or to the axis line on the right trunnion. **Boxwood clinometer.**

The Watkin clinometer is an angular frame of gun-metal which contains a graduated column and spirit level. The brass column is marked in degrees from 0 to 45, and each degree is subdivided into 12 parts, so that a division of the scale reads to 5 minutes. **Watkin clinometer. § 3973.**



To lay a gun with this instrument the drum or column is unscrewed until an arrow on the collar points to the elevation required; this regulates the position of the spirit level. Then the clinometer may be applied to the top of the breech or face of the muzzle, using the long or short side of the frame as required; it can also be used for depression by reversing the instrument in either position. Or, again, it may be used for higher angles than 45° by subtracting the angle from 90°, and setting the drum to this reading; then the opposite limb of the instrument must be applied to the gun to that which would have been used for giving elevation of less than 45°.

Quadrants of any kind may be used for giving elevation, but it is essential that the axis of the trunnions should be horizontal.* For howitzers accordingly a quadrant is made which contains a second **Quadrants.**

* The importance of eliminating error due to difference of level in the trunnions of a gun or in wheels of a carriage will be understood by the following example :—

Let R = range; ϵ = elevation; ϕ = the inclination of the trunnions; and d = the deflection due to this cause. Then it may be readily seen that $d = R \tan \epsilon, \sin \phi$. Suppose the right wheel with a 13-pr. R.M.L. gun to be 1½ inches higher than the left, and the gun to be fired at a range of 2,000 yards. The elevation would be 3° 6′. Sin ϕ may be taken at $\frac{1 \cdot 5}{62}$, when the track of the wheels is 62 inches

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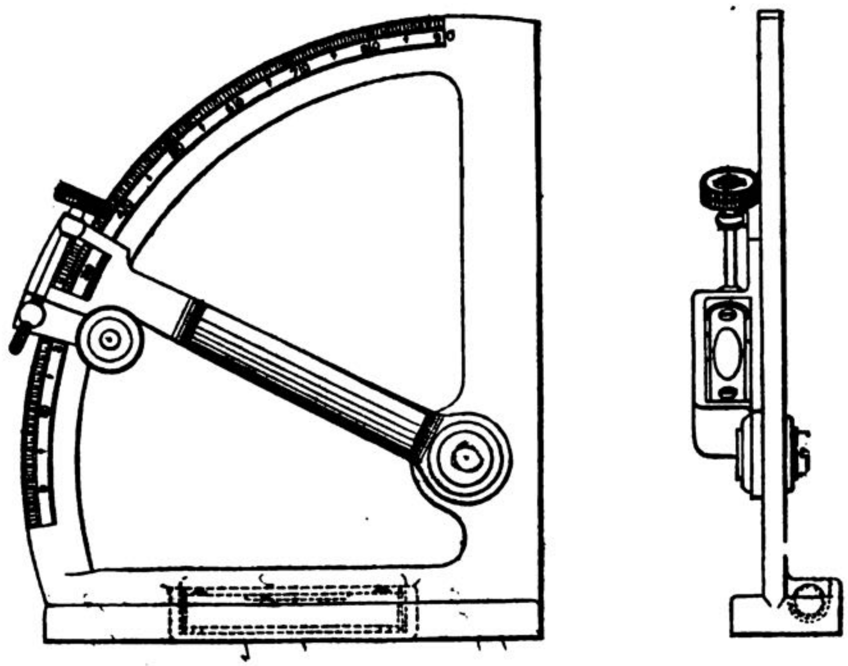
spirit level in the lower limb, to show whether the trunnions are in a proper position. This instrument must be applied to the "quadrant planes" which are cut on the surface of the piece.

QUADRANT FOR LAYING HOWITZERS.



*Graduated Arcs.**

Graduated arcs.

For *direction* only a graduated arc is often laid in rear of the racer of a heavy gun when mounted in a permanent work. This is simply a metal arc, graduated from zero on the left to the extreme limit of traverse on the right. A pointer attached to the rear of the platform indicates the position of the gun when carefully laid; and this can be quickly recovered after each round when firing at a fixed object by bringing the pointer back to the same place on the graduated arc.

*Hanging Scales.**

Hanging scales.

This also is an arrangement for recovering the true line of fire after each round when the object cannot be seen. It can only be applied to wheeled carriages, but no new style of carriage is fitted for these sights, so they are now falling into disuse.

Two scales are suspended under the gun, swinging freely from eye-bolts just clear of the platform or ground. The scale bars are graduated exactly alike to 10° and smaller divisions, and the rear scale is provided with a secondary scale for giving deflection.

$$\text{Then } d = 2000 \tan 30^\circ 6' \times \frac{1{\cdot}5}{62}$$
$$= 2{\cdot}6 \text{ yards},$$

which is equivalent to about 4½ minutes deflection, the shot being thrown to the side of the lower wheel.

The rule of thumb for correction on uneven ground is as follows: that the difference in level (in inches) multiplied by the elevation of the gun (in degrees) will be the amount of deflection (in minutes) to be given on the side towards the higher wheel.

* These stores are manufactured by the R.C.D.

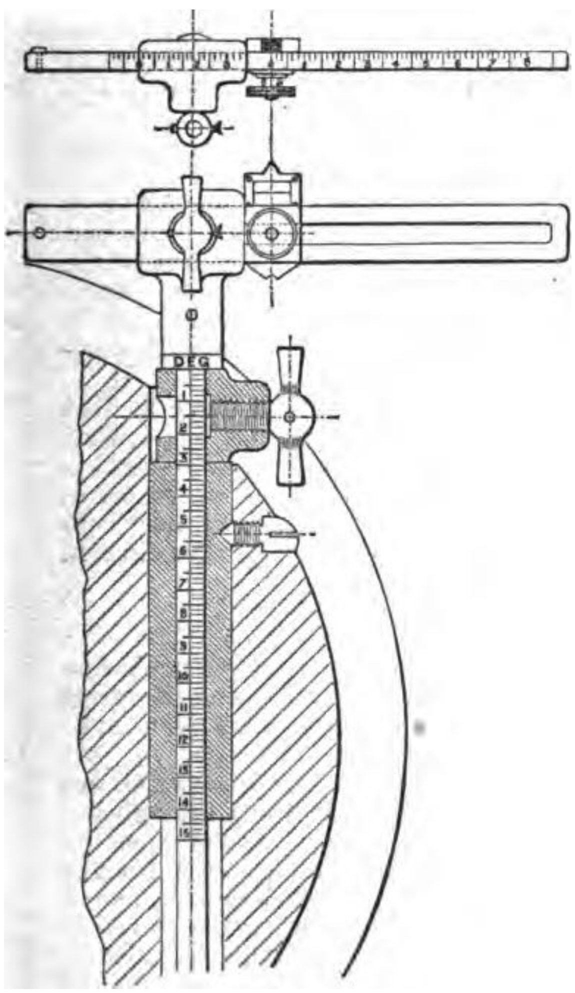
To use hanging scales the line of fire must first be obtained and the gun carefully laid on this line. The direction is then marked on the platform or ground by a chalk line, string, button, or other available means under similar centre figures of each scale. When the gun has been fired and run up again to position the trail only need be moved for alignment, until the same figure on the rear scale covers the line as that which happens to be read off on the front scale. Deflection is given by shifting the rear scale bar as much as required, and then using the main scale.

Cross-bar Sights.

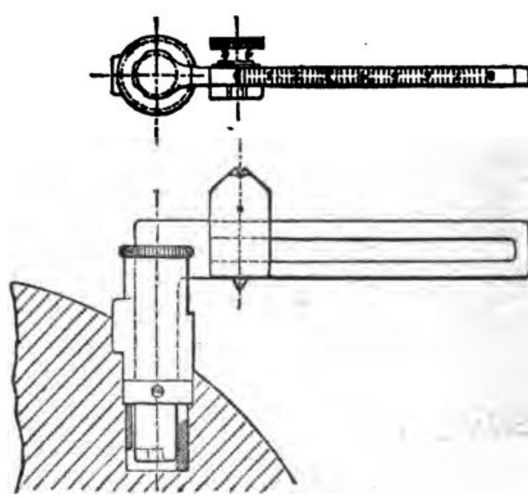
These sights have been prepared from a plan which was proposed by Major G. A. French, R.A. They resemble service sights in everything but the cross-bar at the head. This is made reversible, so that a pair of these sights can be applied to either side of the piece in the case of howitzers; and they can be used for reverse, forward, or direct laying.

Cross-bar sights, § 4012.

TANGENT SIGHT.



TRUNNION SIGHT.



The hind-sights are set vertically in the howitzer, any necessary height being given by means of a removable clamp. The bar is graduated with a tangent scale and the top is fitted with a bronze head, clamping screw, and a steel horizontal cross-bar. This bar, which is graduated from

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0 to 8 with smaller divisions, is capable of being moved to the extent of 1° to the right and 3° to the left, to afford compensation for drift, wind, &c. The cross-bar itself is provided with a sliding and reversible leaf, having a pointed sight at the top for rough laying and cross-wires below. There is also a notch underneath for forward laying when the leaf is turned upside down.

The trunnion or fore-sight consists of a steel stem, fitting into a gun-metal socket on the "drop" system, with a fixed cross-bar, which is also provided with a sliding reversible leaf and is graduated in the same manner as the cross-bar on the hind-sight, viz., from 0 to 8, and in smaller divisions.

Mode of use.

For reverse laying the notch on the trunnion sight is used in conjunction with the point on the hind-sight, or the eyehole with the cross-wires.

For forward laying the leaves must both be turned over and the notch of the hind-sight is used with the point of the fore-sight; for fine forward laying the sliding leaves can be exchanged by removing the mill-headed clamps.

For direct laying the method is the same as when using service sights of ordinary pattern, elevation being given on the tangent scale and deflection on the cross-bar; only care must be taken that both sliding leaves are clamped at corresponding divisions, to obtain a line parallel to the axis of the gun.

Deflection is given in all cases by shifting the cross-bar of the hind-sight, still using corresponding divisions on the main scales.

When using these sights for indirect laying the line of fire must first be obtained and marked out in rear or in front of the gun. This will show the direction, while elevation must be given by means of the clinometer or quadrant. If near the platform one of the aiming pointers must be a plumb line. After the first round corrections can be made in elevation or line, and when one distant aiming point is used the clinometer may be dispensed with.

The principle of using the cross-bars is exactly the same as that already described for hanging scales; *i.e.*, after firing each round, when the gun has been brought back to position, the leaf of the fore-sight is clamped in line with the aiming points, and the other at the corresponding mark on the scale; then the trail only is moved until both sights cover the aiming points: the axis of the piece is thus directed always in parallel lines.

Turret Sights.

Turret sights.

Guns mounted in moveable turrets are placed on carriages worked on fixed slides, so that "direction" must be given by traversing the turret itself while elevation is given on the gun; the turret, therefore, must be furnished with means for obtaining the line of fire.

Each turret has three or five "man-holes" in the roof, which are called from their position centre, intermediate, and wing; through any of these the captain of the turret can look over the sights and direct the laying of his guns. A fore-sight and hind-sight are placed in front of each man-hole, so adjusted that when the latter is set at zero the line of sight shall be parallel to the axes of both guns when the elevating arrangements are at zero. For sea service sufficient height must be given to the sights for the line to clear the edge of the turret when the vessel is heeling away from the object, to the extent of about 4°. Other sights are provided for greater angles of heel.

Old pattern turret sights.

The old pattern hind-sights are graduated to 4° for heel either way, and are raised or lowered by means of a hand-wheel. This graduation, however, must not be confounded with the degrees of a hind-sight for

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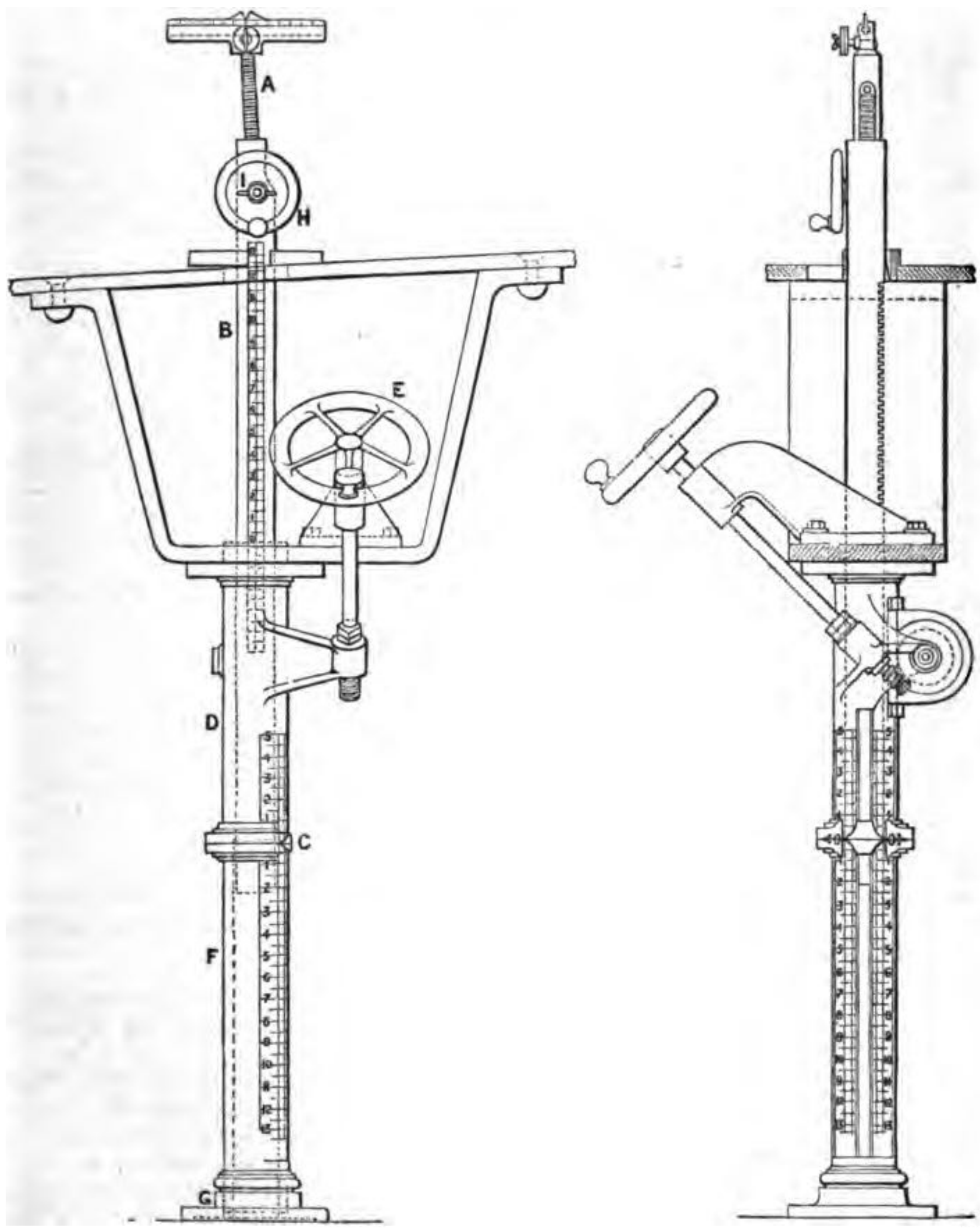
giving elevation to the gun, it is merely a provision for making correction for heel. These sights are fitted with two traversing leaves, one for drift, which is graduated according to range, and the second for wind, speed, and other corrections.

All turret-ships are now being provided with "compound sights," which are fitted to the centre and intermediate man-holes, or to the centre and wing in cases where it is impracticable to fit them to the intermediate position.

COMPOUND HIND-SIGHT.



Compound turret sights. § 3802.

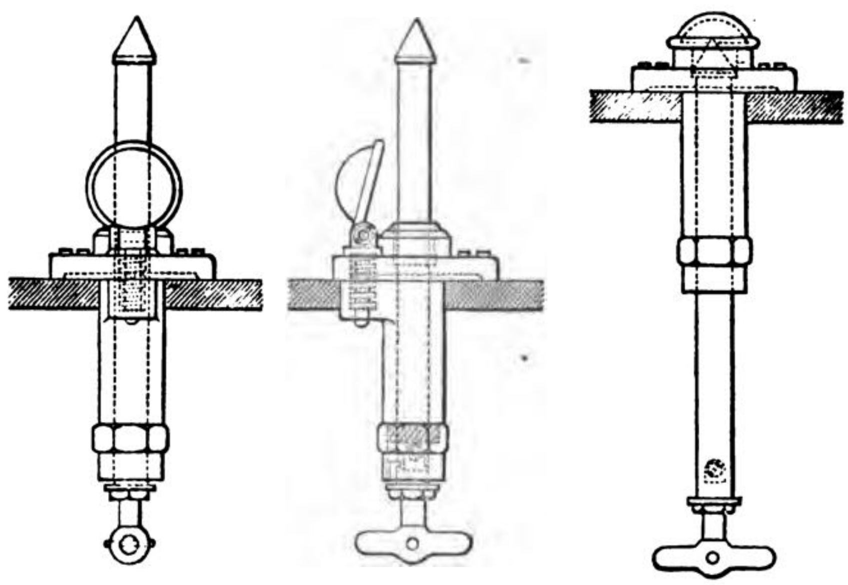
The compound sight consists of an outer and inner bar; the inner bar A is of steel, graduated in yards and provided with a cross-head and leaf for such deflection as may be required for variable

CHAP. III. causes. The outer bar B is of bronze, and in the upper part of this bar the steel sight is capable of being raised or lowered by means of a hand-wheel and pinion H, at the permanent angle of correction for drift.

The compound sight works up and down in a socket D, being provided with worm gearing and rack-and-pinion motion, which is actuated by a shaft and hand-wheel E. The lower portion of the socket F is called the guard tube (a separate store), which serves the double purpose of protecting the bar and of receiving a scale of elevation, which is prominently marked upon it; a scale for depression is similarly marked above the zero line on the socket. The bronze bar is fitted with a reader C, which being attached to the lower end of B, travels in a slot through the centre of the scale on the guard tube and indicates the exact elevation which is to be given to the gun. The bottom of the guard tube is fixed on a footstep or some other suitable support.

The fore-sight consists of a pointed steel spindle, with cross-handle at the lower end. This fits in a bronze socket in the roof of the turret, which is supplied with a spring cap. When not required for use the sight is lowered and housed; for action it is pushed up and locked in position by a bayonet joint.

FORE-SIGHT.



Sight elevated for use. Sight housed when not required.

To use these sights the steel bar of the hind-sight is raised to the estimated range by turning the hand-wheel marked H and then clamped by the nut shown at I.

The compound bar is next lowered by means of the hand-wheel E until the line of sight covers the object, the direction being obtained by traversing the turret itself. The reader will now record on the guard tube the exact elevation or depression at which the gun should be laid. Correction for drift and heel of the ships are both automatically made, no words of command are required, and correct elevation of the guns is ensured by graduations on the elevating gear.

Reflecting Sights.

Mirror sights are only fitted to ordnance mounted on some nature of elevated carriage or behind small ports where the eye cannot look directly over the sights; they are supplementary to the service sights, which are generally issued as well. **Mirror sights.**

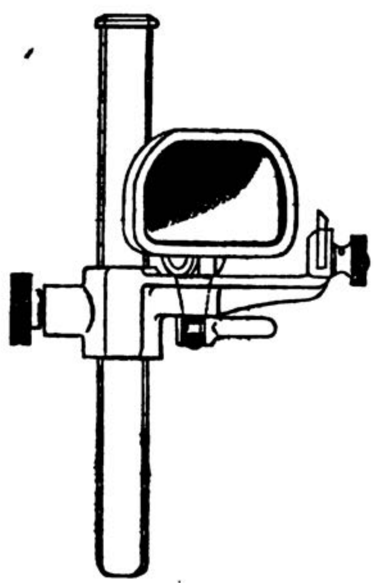
Chase Sights.

Chase sights have been fitted to 10-inch and 12-inch R.M.L. guns and to all heavier natures when mounted behind iron shields, where it is found that the line of sight over the breech is intercepted by the edge of the port. They are practically service sights placed on the chase of the gun, with a reflector pivoted behind the notch of the hind-sight, to take the place of the eye which cannot be applied in that position. **Chase sights.**

The fore-sight is of the usual drop pattern, fitting into a metal socket, let into the chase 30 inches in front of the hind-sight. When the gun is run out to a firing position this sight may be outside the port.

The hind-sight is a steel bar, graduated for a 30-inch radius, with a gun-metal arm, which carries the mirror and leaf. This arm is capable of sliding up the steel bar, and should be clamped at the required eleva-

MARK II.*

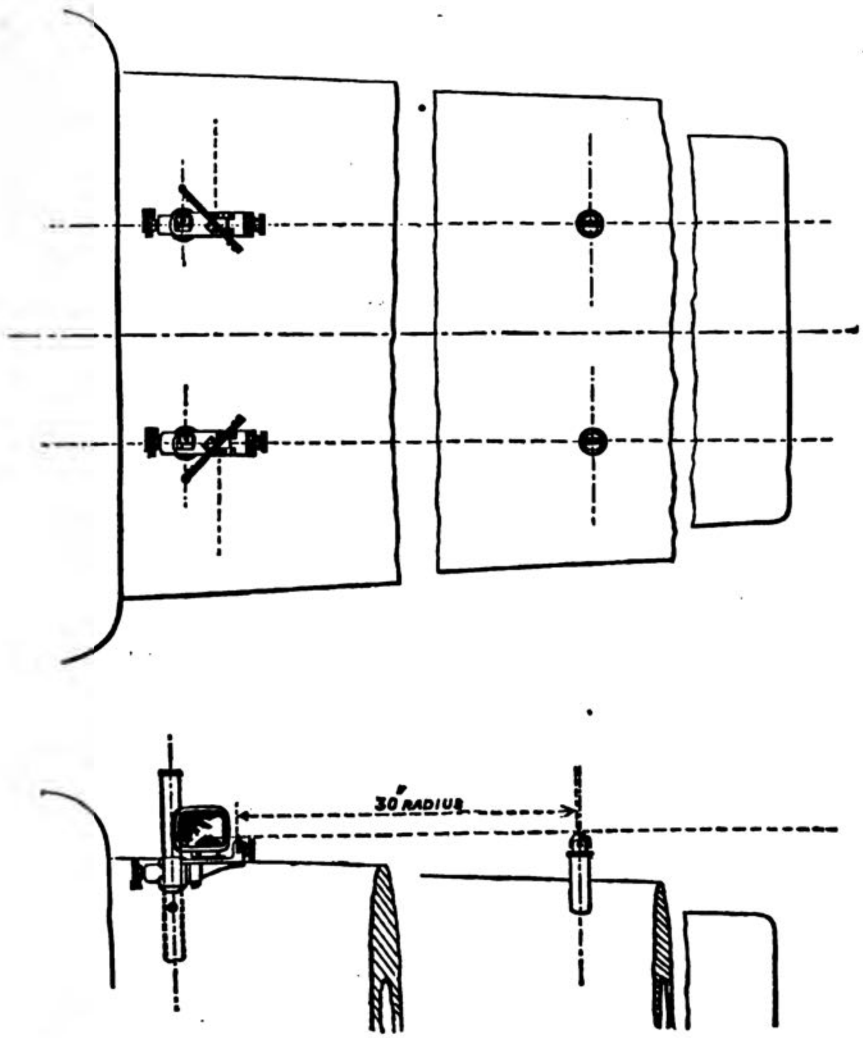


tion. Deflection can be given right or left to the extent of one degree thirty minutes on the sight leaf. The mirror can be turned on its pivot in a horizontal plane, and its face is inclined downwards to suit the position of a man laying the gun. A pair of sights are provided for each side of the gun, and they are made interchangeable.

* The Mark I sight differs from the one here described only in the amount of deflection, which is limited to half a degree, and in having no clamping screw.

CHAP. III.

CHASE SIGHTS.



To use these sights the man must stand with his back to the port and adjust the mirror to his position; then the gun is laid by bringing the object and fore-sight in line with the notch, which is clearly seen in the mirror. The hind-sight should be removed from the gun before firing.

Sights for Moncrieff Carriage, Mark I.

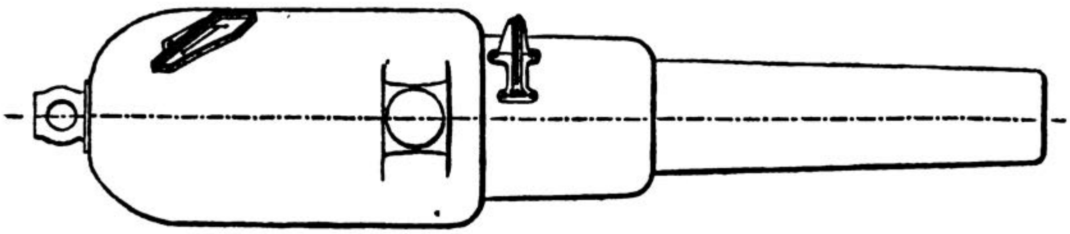
Sights for Moncrieff carriage, Mark I. §§ 2434, 3636.

Only 7-inch R.M.L. guns of 7 tons have been mounted on this nature of carriage and fitted with these particular sights.

The fore-sight is a graduated skeleton frame of gun-metal, attached by screws to the side of the gun on the coil in front of the trunnions. The sight notch may be clamped by a thumbscrew at any range marked on the scale, being *lowered* to give elevation.

7-INCH R.M.L. GUN, 7 TONS. CHAP. III.

Sketch shewing position of Sights.



The hind-sight is a mirror secured to the side of the breech with cross-lines like a ┬ on the face, so adjusted that a ray from the object through the fore sight to the intersection of the lines on the mirror should be thrown down into the gun pit; the gun may be laid in this manner without exposure of men. There is no arrangement for giving deflection, so these sights should only be used at close quarters.

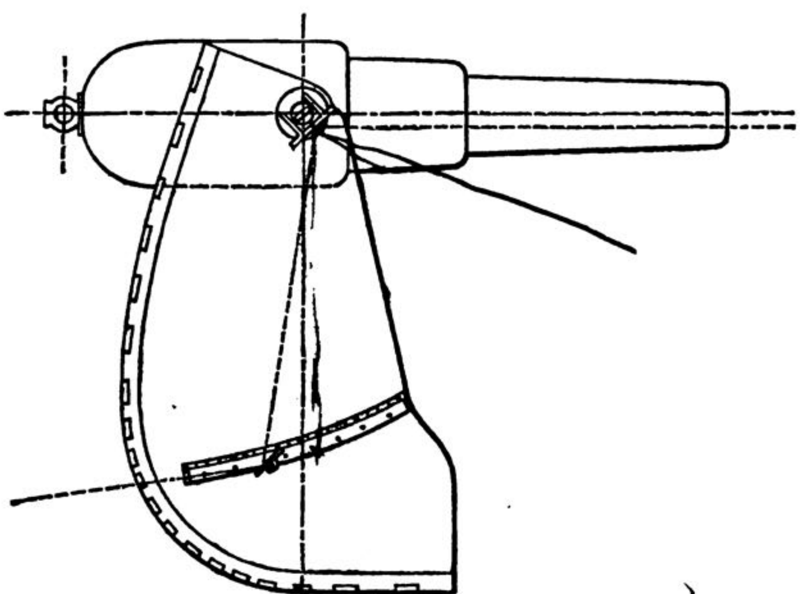
Mirror Sights for Moncrieff Carriage Mark II.

Sights for Moncrieff carriage, Mark II. § 3636.

7 and 9-inch R.M.L. guns, 64-prs. of 58 cwt., and 7-inch B.L. screw guns of 82 cwt. have been mounted on the Moncrieff system Mark II; the special sights for these guns when so mounted consist simply of two mirrors and a graduated arc, each mirror having cross-lines cut on the face, which, however, do not actually intersect one another to avoid spoiling the glass where the object ought to be seen.

7-INCH M.L. GUN, ON MONCRIEFF CARRIAGE MARK II.

Sketch shewing position of Reflecting Sights.



One mirror is attached to the end of the right trunnion by a circular

CHAP. III.

bracket, and the other is fixed in a sliding frame which can be clamped at any part of the graduated arc secured to the side of the elevator.

To lay the gun, the lower mirror must be set at the figure on the scale corresponding to the angle of elevation required; then the gun must be trained for direction and laid with the elevating gear, so that the reflection of the object in the upper mirror is distinctly seen in the lower. There is no arrangement again in this case for giving deflection either for drift, force of wind, or speed in the object.

These sights are, strictly speaking, only correct when the difference of level between the gun and the object is too small to be of any importance. The mode of adjustment and rules for correction when there is any appreciable error from height will be found in the Appendix at the end of Part IV.

Mirror Sights for 6·6-inch and 100-ton R.M.L. guns.

Sights for 6·6 inch and 100-ton guns. §§ 4373, 4372.

These sights, being at present confined in each case to a particular kind of gun, will be described in the next chapter among the special fittings belonging to these natures of ordnance.

FITTINGS AND SMALL STORES.

Fittings and stores.

We come next to the fittings and stores for R.M.L. guns; a full list will be found in the table at page 173, but a short description is here given of some of them.

Bearer, shot or shell.

§§ 1320, 2207, 2981, 3112, 3676, 4000, 4001.

This is required with 80-pr. and all heavier guns up to the 9-inch inclusive, when muzzle derricks are not provided. They are also supplied with all howitzers except 6·3-inch. There is a Mark II for 7- and 9-inch R.M.L. guns, which is stronger than Mark I; and there is a strengthened pattern which does not constitute a second mark for the 8-inch howitzer of 46 cwt.

Cascable, Slinging, removable.

Used with those guns axially vented. The bronze vent socket is removed (when the gun is for transport) and the cascable screwed into the hollow disclosed.

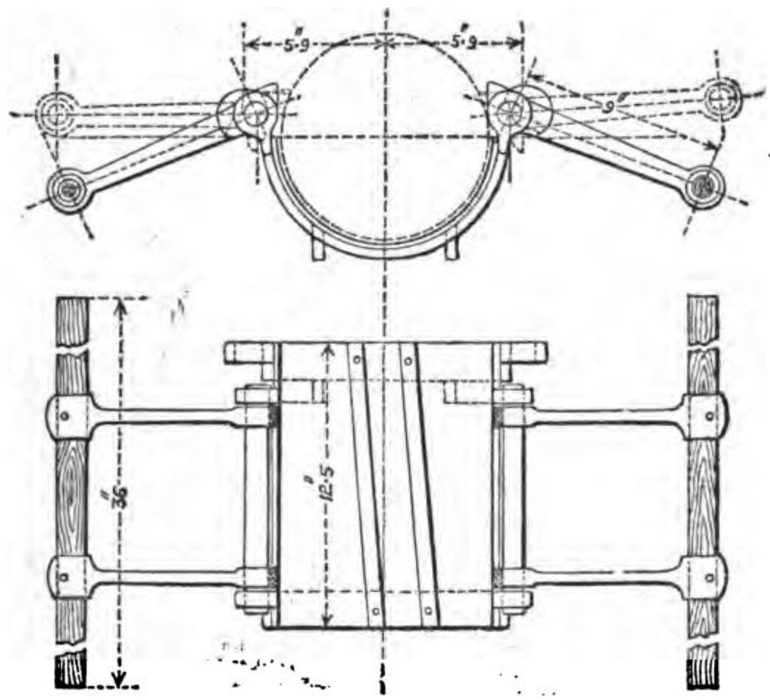
Counter-balance, muzzle.

Used with the 100-ton to correct preponderance for transport. It consists of a ring of cast-iron (weighing 30 cwt.) with loops for slinging and three clamping screws for fixing it. It is placed on the muzzle, which is prepared specially to receive it.

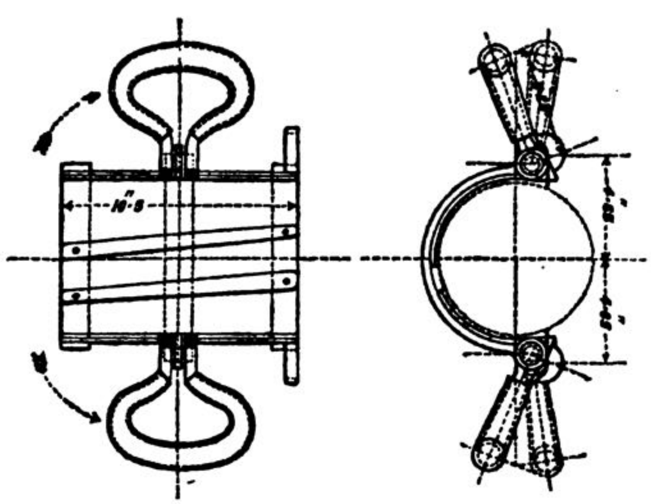
Cradle, wood, vent.

Is used with those guns axially vented for inserting the vent. This has to be passed down the bore and pushed through the hole in the breech, and the cradle is supplied to effect this. The screwed end of the vent being caught as it protrudes and held, the cradle can be withdrawn, the guide blocks which have to pass the head of the vent becoming disengaged (p. 172). The acorn guide (A) is inserted into the end of the vent to facilitate its passage into the hole in the breech.

SHOT BEARERS, L.S. 9-INCH R.M.L. GUN.



7-INCH R.M.L. GUN.

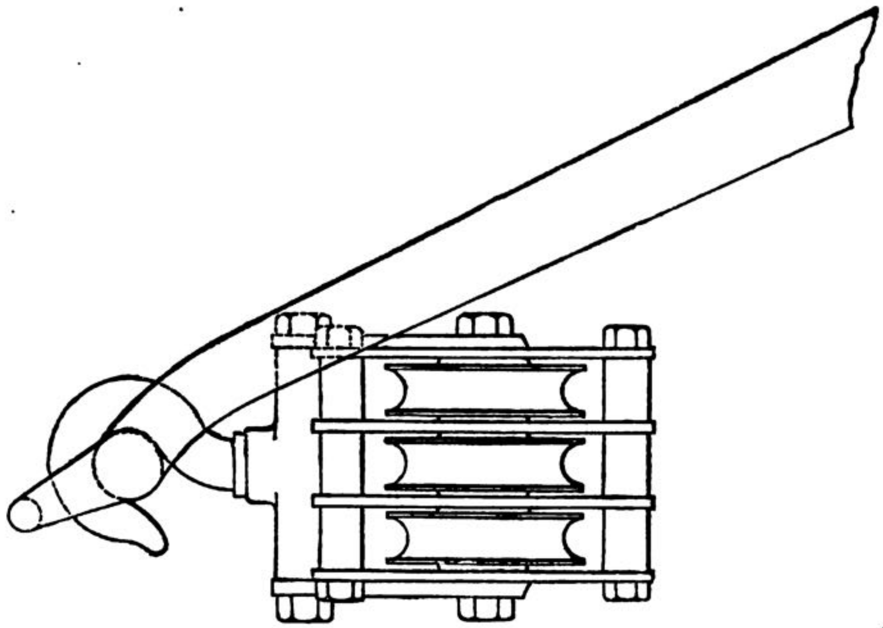


Bolts, iron, elevating eye, with washer and keep-pin.

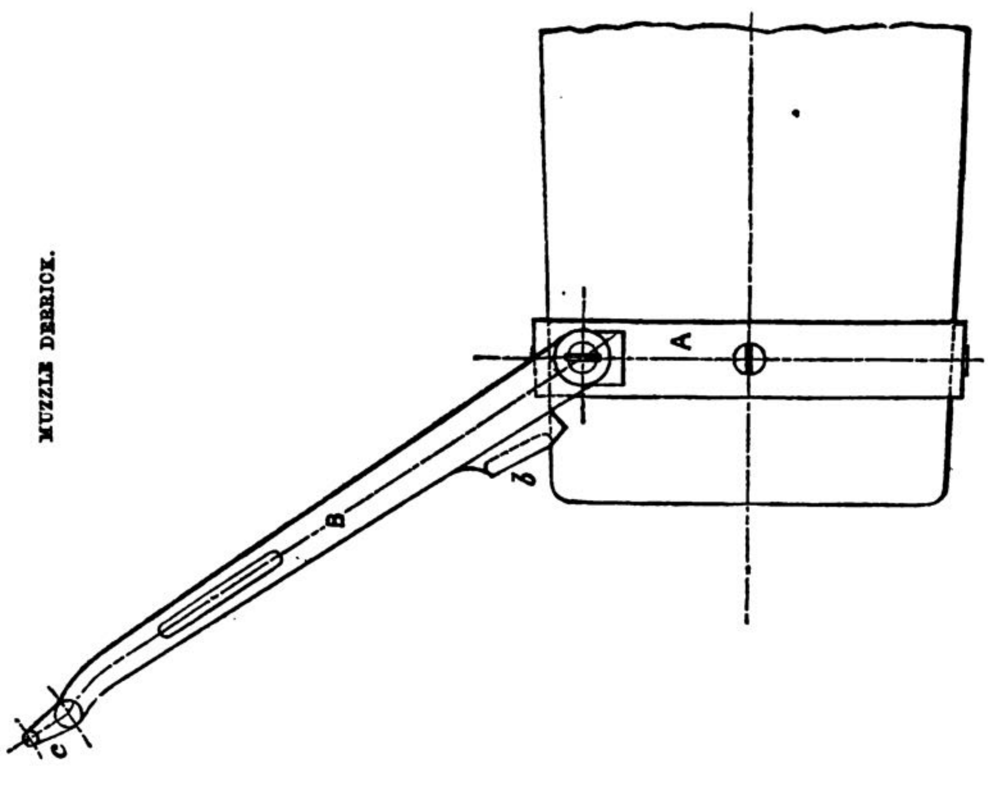
These are supplied with 9, 13, 16 and 25-pr. R.M.L. guns, and the parts are interchangeable among all these pieces except the bolt for a 9-pr. gun of 6 cwt., which is shorter than the bolt for the others.

CHAP. III.

SKETCH SHOWING METHOD OF ATTACHING THE BLOCK.



MUZZLE DERRICK.



Derricks.

CHAP. III

This fitting is provided for L.S. only with 9-inch and all heavier guns up to 12·5-inch 38 tons, for the purpose of raising the projectile up to the muzzle; but it is not used with guns which are mounted behind iron shields. It is made of bronze, and consists of a band (A) fixed round the chase at a distance of 7 to 12 inches from the muzzle, according to the nature of the gun, and a derrick (B) secured to the band by two bolts. The derrick has a "bridge-piece" (*b*) which rests on the gun, supporting the upper part of the derrick which projects over the muzzle. The tackle should be hooked into the eye at the top (*c*) with the back of the hook towards the gun and the point *through* the loop to prevent the tackle from slipping. The band is secured to the gun by four screws; the derrick should be turned back on the chase after loading, and always kept there when not being actually used. (See figure, page 164.) § 3007.

A Mark II has been sealed for 10-inch R.M.L. guns, because at some ranges the Mark I might be liable to interfere with the line of sight.

Instructions for the adjustment of derrick-bands will be found in the Appendix at the end of Part IV (p. 381). § 3769.

Extractor, vent-sealing tubes.

These are required with all axial vents to extract the tube after firing, because it is liable to get set fast in the vent by expansion under pressure of the gas.

Guard, vent.

These are provided for 10-inch R.M.L. guns, when mounted on gun-boats of the "Blazer" class, to prevent injury to the men from the flash of the vent, the guns being mounted lower than usual. Also for 8-inch R.M.L. guns on board the "Sultan" with a slight alteration of form to suit electric tubes. § 2118.

Holder, tube (see *Vent, axial*).

Lanyard guide.

The guide-plate is a S.S. fitting for all natures of guns. It is made of steel, and is screwed into the right rear of the vent to guide the lanyard which is passed through it, to give a direct pull on the quill §§ 476, 688.

tube. It has a cross-head to which a loop on the lanyard can be attached when the gun has been loaded to prevent its being fired accidentally.

CHAP. III.

Machines, hand, rifling.

§ 4110. These instruments are supplied for all heavy guns of 7-, 9-, 10-, and 11-inch calibre, and for 12·5-inch. They are intended for repairing the grooves when the gun has been injured by premature explosion of a shell, or accident of any other kind. A machine for muzzle-loading guns consists of an iron tube in two lengths, which can be used separately or united together; it is furnished with a head, stop, and guide of bronze metal, and a cross handle of iron. Two files are issued, one for the lands and the other for the grooves which are attached to a spindle in the head of the machine when fitted for use, with a spring and regulating nut to keep the file up to its work.

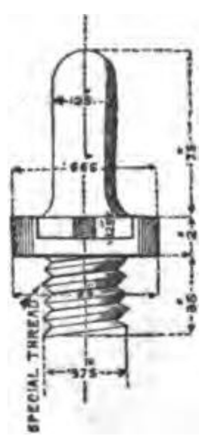
The guide and stop are in two parts, connected by screws and they can be fixed anywhere along the length of the tube. A set screw secures the spindle when filing the lands: care should be taken to slacken this screw when filing the grooves, to allow the file to adjust itself to the pitch. In rear of the file a hole is tapped for another screw, the head of which conforming with the groove acts as a guide when filing the edges with the broad file; this guide should be replaced by a preserving screw when filing the bottom of the grooves.

Patch, preserving muzzle-sight.

§ 4111. This small store is intended to fill up the seat of the muzzle-sight on 9-pr. 6 cwt. guns S.S., when the latter has been removed for transport, &c. It is made of cast iron, and is secured to the gun by two screws.

Pin, friction-tube.

§ 1141. The friction-tube pin is a S.S. fitting for all natures of guns; it is screwed into the surface of the breech 1·3 inches to the left front of the vent. A spare hole is made adjoining to this in case the pin should be



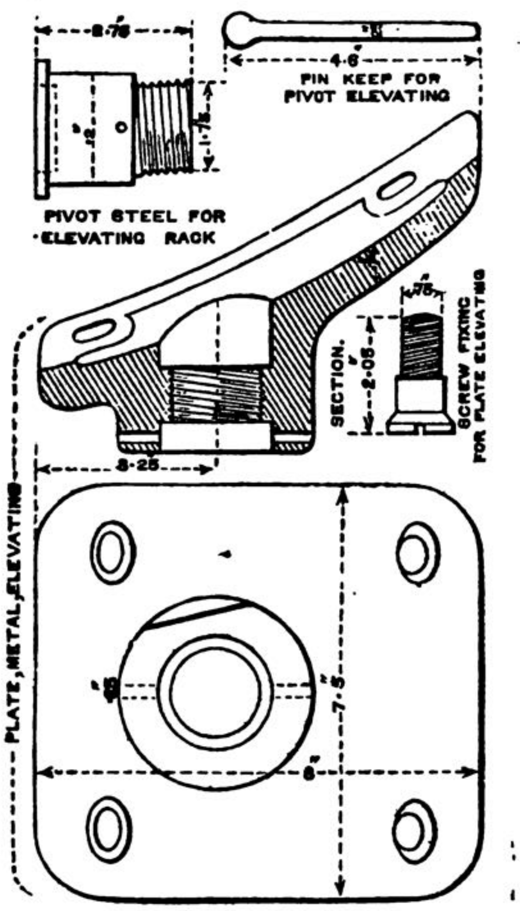
broken off in the first hole. The leather loop of the tube is placed over this pin, to prevent the quill from being broken when the lanyard is pulled.

Plates, elevating, for elevating arc.

These fittings consist of a steel pivot, a metal elevating plate, a keep-pin, and the fixing screws. §§ 1435, 1647, 3543, 4178, 4179.

The metal plates are right and left handed, except for 35 and 38-ton guns, which have two plates attached to the same side of the breech.

DETAILS OF AN ELEVATING PLATE FOR 9-INCH R.M.L. GUNS, 12 TONS.



For 10-inch and heavier guns a Mark II has been sealed, sometimes termed "countersunk," as they have a square or hexagonal boss which must be fitted into a recess cut in the gun: this method of attachment relieves the fixing screws of much strain.

The steel pivots are screwed into the plate, and held in position by the keep-pin. They serve to connect the gun to the elevating racks on the carriage. To fix the rack the keep-pin must first be removed, then the steel pivot unscrewed, and after being passed through the hole in the rack it is screwed again into the plate; the keep-pin must then be replaced.

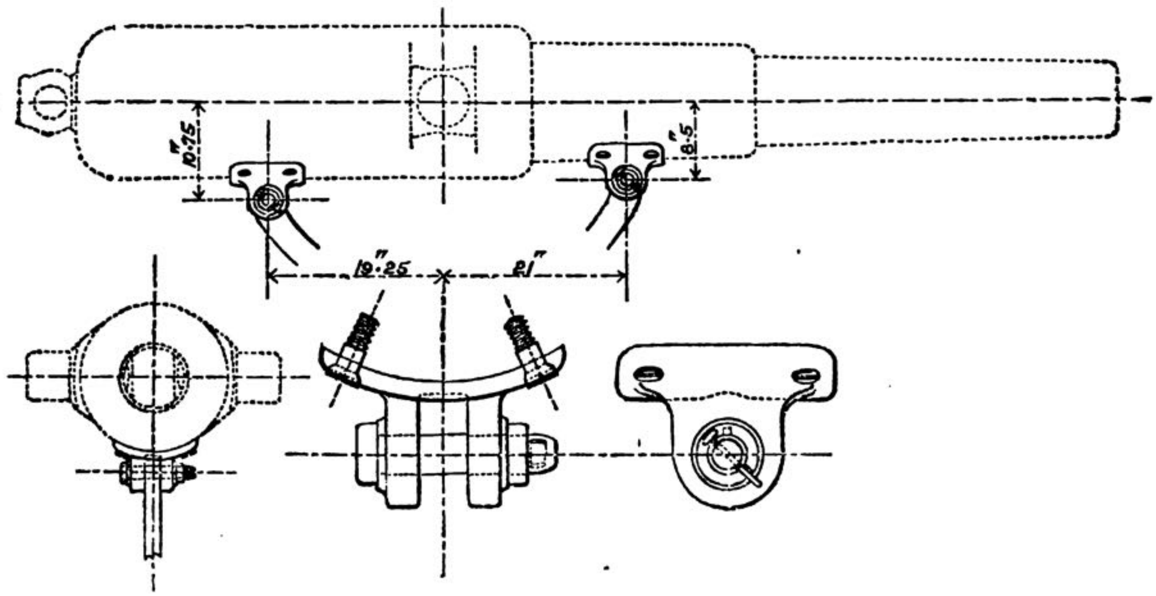
There are different patterns of elevating plates for small-port and

CHAP. III. ordinary carriages,* for which reference, if necessary, must be made to the Changes of War Stores quoted in the margin.

Strengthened pivots also have been approved for 35 and 38-ton guns, which are not distinguished by a separate Mark.

For overbank carriages special plates are required, which are attached underneath the gun, one near the breech, and the other in front of the trunnions; the ends of the elevating rack are attached by steel bolts to the plates.

PLATES, ELEVATING, COMPLETE (BREECH AND MUZZLE). MARK II (for Overbank Carriage).



Prickers or priming irons.

§ 3170. Prickers for R.M.L. guns are issued of the following lengths:—

$7\frac{1}{2}$	inch,	for	field and boat guns.
12	,,	,,	siege, garrison and naval guns under 6 tons.
17	,,	,,	7 and 8-inch guns.
23	,,	,,	9 to 12-inch of 25 tons.
29	,,	,,	35 and 38-ton guns.

They are made of steel tempered in oil.

---

* The following are the marks of pivot pieces (dependent on the form of the plate metal elevating) for the different natures of guns:—

Mark I for 12"·5 M. I; M. II for 12"·5 M. I mounted on small port carriages and is central only. M. I or II for 12" of 35 tons; M. I or II for 12" of 25 tons M. II; M. I or II for 11" M. II; M. III for 11" M. II ("Alexandra" and "Temeraire" class); M. IV for 11" M. II Barbette of "Temeraire" to suit Armstrong elevating arrangement); M. I or II for 10" M. II; M. III for 10" M. II on small port carriages; M. IV for 10" M. I (has a strengthening boss); M. I for 9" M. I; M. II for 9" M. III; M. III for 9" M. II, IV, or V; M. IV for 9" M. I fitted for "Sultan" class; M. I for 8" M. I; M. II for 8" M. III; M. I for 7" M. I; M. II for 7" M. III; M. I for 7" of 90-cwt.: M. I for 64-pr. M. II; M. I for 64-pr. M. III; M. II for do. (for overbank carriage): M. I for 40-pr. M. I; M. I for 40-pr. M. II; M. II for do. (for overbank carriage); M. I for 8" howitzer; M. I for 25-pr.: Mark II for 25-pr. (overbank carriage); M. I for 20-pr. R.B.L. 15 cwt., M. I; for 20-pr. R.B.L. 13 cwt.

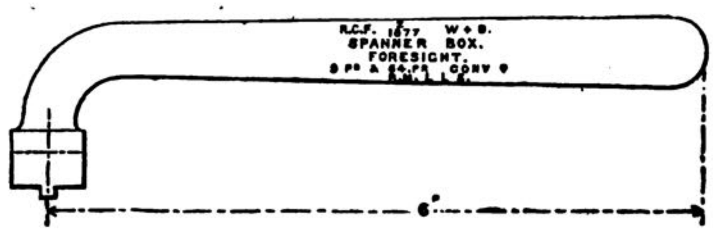
Set-screws, tangent sight.

Set-screws, right and left, are supplied with 16-pr. guns, to clamp the hind-sight when raised for laying the gun. They are secured in the gun by a screw pin, which is placed so as to prevent them from being unscrewed.

Wrench sight, R.M.L. muzzle, hog-back.

This is used for fixing or removing the fore-sight on a 9-pr. L.S. gun or 64-pr. of 58 cwt. A strengthened pattern has been approved which differs from the earlier tool in having a longer projection, and in being rounded off at the outer edge. §§ 3245, 3853.

(Formerly termed) SPANNER, BOX, FORE-SIGHT.



Wrench, sight, R.M.L. fore.

For removing and fixing the screw trunnion sights on a 16-pr. R.M.L. gun. § 3246.

Wrench, nut, vent.

This tool is required to fix or remove the nut which secures the vent-bush in its axial position in 38, 80, and 100-ton R.M.L. guns.

Spikes, common and spring.

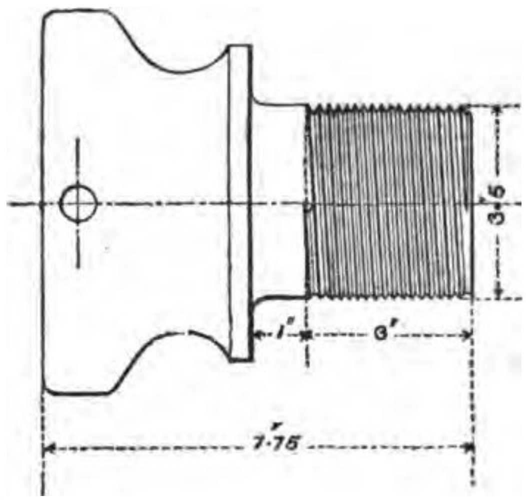
Both kinds of spike are the same as those used with S.B. ordnance. With regard to spring spikes, the length suitable for each nature of gun is given below.

Spike Spring.	Length in inches.	
A	15·5 ..	R.M.L. 9-inch, 8-inch, and 7-inch 6½ ton, Mark I.
B	12·5 ..	R.M.L. 7-inch 7 ton and 6½ ton except Mark I 6½ ton) 80-pr. and 64-pr. 71 cwt.
C	9·2 ..	R.M.L. 8-inch 70 and 46 cwt. howitzers; 6·6 inch 64-pr. and 58 cwt., and 40-pr. Mark I guns.
D	6 ..	R.M.L. 6·6 and 6·3 howitzers 40-pr. Mark II 25- and 15-pr. guns.
E	3·5 ..	R.M.L. 13-pr., 9-pr., 7-pr. and 2·5-inch guns.

CHAP. III.

Studs, trunnion.

§§ 3422, 3433. These have been fitted to nearly all guns of 38 tons' weight and upwards to facilitate the work of mounting in casemates, especially in



conjunction with hydraulic jacks, and the box girder frame. All guns recently issued have been prepared for the reception of these studs, but it is not necessary that they should be issued with each gun; preserving screws should be inserted in their place when the gun has been placed in position.

Washer, iron, for trunnions.

§ 3424. This article is used in connection with trunnion studs, being screwed on between the face of the trunnion and head of the stud, to prevent the chain from slipping on to the trunnion when raising the gun.

Wrenches, for elevating racks, index-plates, and derricks.

§ 3686. There are four kinds of wrench for this purpose.

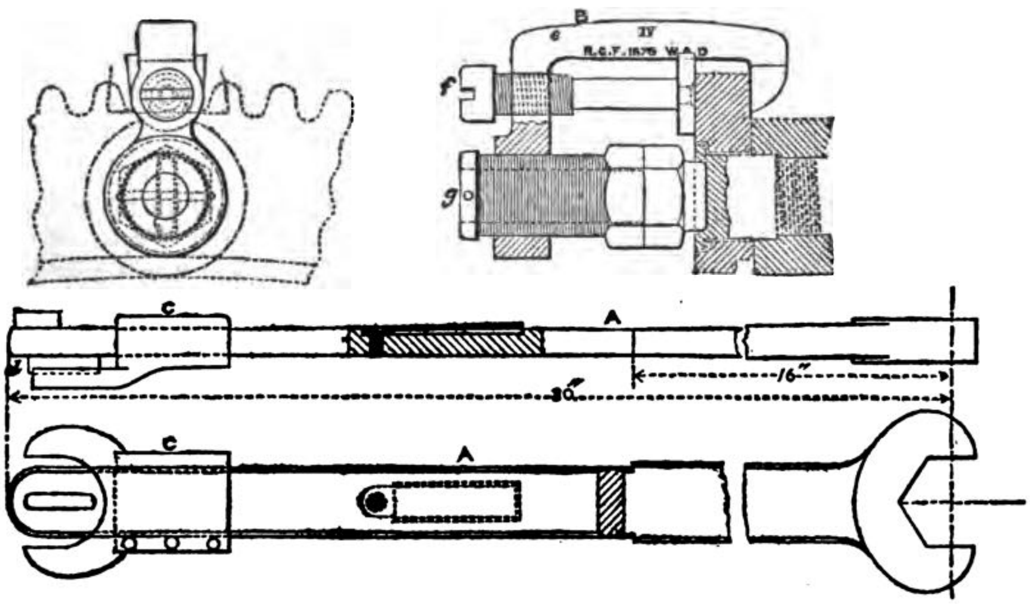
No. 1 wrench (formerly called Mark IV, and probably stamped with that numeral) with clamp and tommy, is used for 7-inch R.M.L. guns and upwards. The tommy has been added as a separate tool since the wrench was first issued for service for driving out the keep-pin of the elevating pivot.

This wrench consists of two parts; only the one marked A in the figure need be used to remove the pivot-piece when the elevating arc is not secured to the gun, but both are required when the arc is attached.

Part A is a wrought-iron bar with a wrench at one end and a projecting stud at the other, which will fit into the slot on the face of the pivot. Under this end slides a jaw C which may be kept in the middle of the bar by a spring when not required for use.

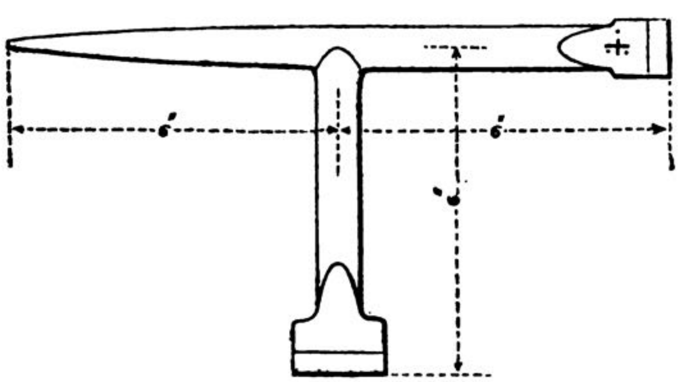
To remove a pivot, place the stud in the slot and slide the jaw over the piece behind the head of the pivot; then unscrew, the keep-pin of course being previously taken out with the tommy.

When the elevating rack is attached to the gun the part B must first be screwed into position as shown in the figure; the clamp *fe* is



attached to the rack, and the spindle *g* thus secured to the pivot piece. Then the other end of the wrench can be applied to the hexagonal part of the spindle, which is free to recede as the pivot comes out, while contact is always maintained by the screw-thread in the clamp.

No. 2 wrench, for 64-pr. and 40-pr. R.M.L. guns, and all howitzers. The numeral II may be found on this wrench according to the old



designation. It is a tool with three limbs as shown in the figure, comprising two turnscrews of different sizes and a tommy.

No. 3 wrench, for 25-pr. R.M.L. and 20-pr. B.L. screw guns This being the first pattern of wrench for these guns is stamped as Mark I. It resembles the No. 2 wrench in appearance, but differs in the size of its turnscrew and length of limb.

No. 4 wrench, in two parts with a tommy. For siege R.M.L. § 4542.
ordnance, and certain breech-loading guns, to supersede Nos. 2 and 3. The parts are stamped "Part I" and "Part II." The tommy is the same as that issued with wrench No. 1.

CHAP. III.

Wrench, sight, S.B.

This is a tool with four arms, viz.:—
(1) Box wrench, for removing and fixing the friction tube pin.
(2) Spanner, for the fixing screws of sights.
(3) Tommy, for extracting the lanyard guide, &c.; and
(4) Screwdriver, for the sight-screws, and general use.

Shutter.

Is a hinged door closing up the axial vent arrangement for safety in firing. It is shown in the cut. It hinges on the left side to the vent bronze socket, and has a hinged handle on the right which works the latch. Guide pulleys are attached to give a direct pull on the friction tube (when used), and leading to the side; one is a fixture, the other is carried on the end of an arm bolted to the shutter by a removable pin for convenience of packing, &c. The centre of the shutter is closed by a screw-plug with octagonal head, two forms of plug being supplied, one with a central perforation when friction tubes are used, the other plain for electric firing, the wires being then led out between the shutter and socket on the right hand side where a spring clip is provided. Spiral springs actuate the bolts of the latch.

Vent, axial.

Shown in cut (K), is passed through the metal of the gun, and a double key (L) slipped over it, which by feathers engages in slots in both gun and vent, and so prevents this turning round, and then a nut (M) is slipped over the end, and screwed (by means of a box spanner supplied) till the head of vent is drawn into close contact with metal of gun. In the 100- and 80-tons the double key is supplied in halves. A copper washer is put on the vent before insertion, and this seals the joint at the head.

Other stores in connection with this axial vent are the bronze socket (A) attached to the gun by fixing screws; the guide (F) attached to the socket by fixing screws, and the "Holder tube" (H), which is a separate store. This tube holder carries the tube, and is attached to the end of the vent by an interrupted screw; a projection on it fits into a groove in the guide (F), which thus ensures that the holder is properly put on. N is the tube, which is of the "V" pattern; it is inserted into the holder while away from the gun, the long wire protruding its loop through the channel, while a spring clip catches the head of the tube and holds it in position.

The tube holder is supplied with two handles for turning it into the locking position; these interfere with the closing of the shutters. unless the locking position of the holder has been properly attained and thus form a tell-tale.

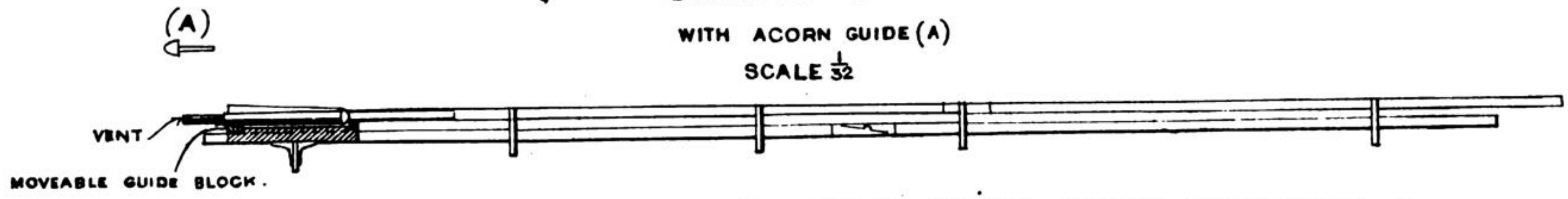
An important point in connection with these vents is to observe that after firing the vent has not become loose owing to compression of the copper washer, and it is advisable under any circumstances to remove the bronze socket (or "frame") after a day's practice and tighten up the nut (M).

To face page 172.

CRADLE VENT.

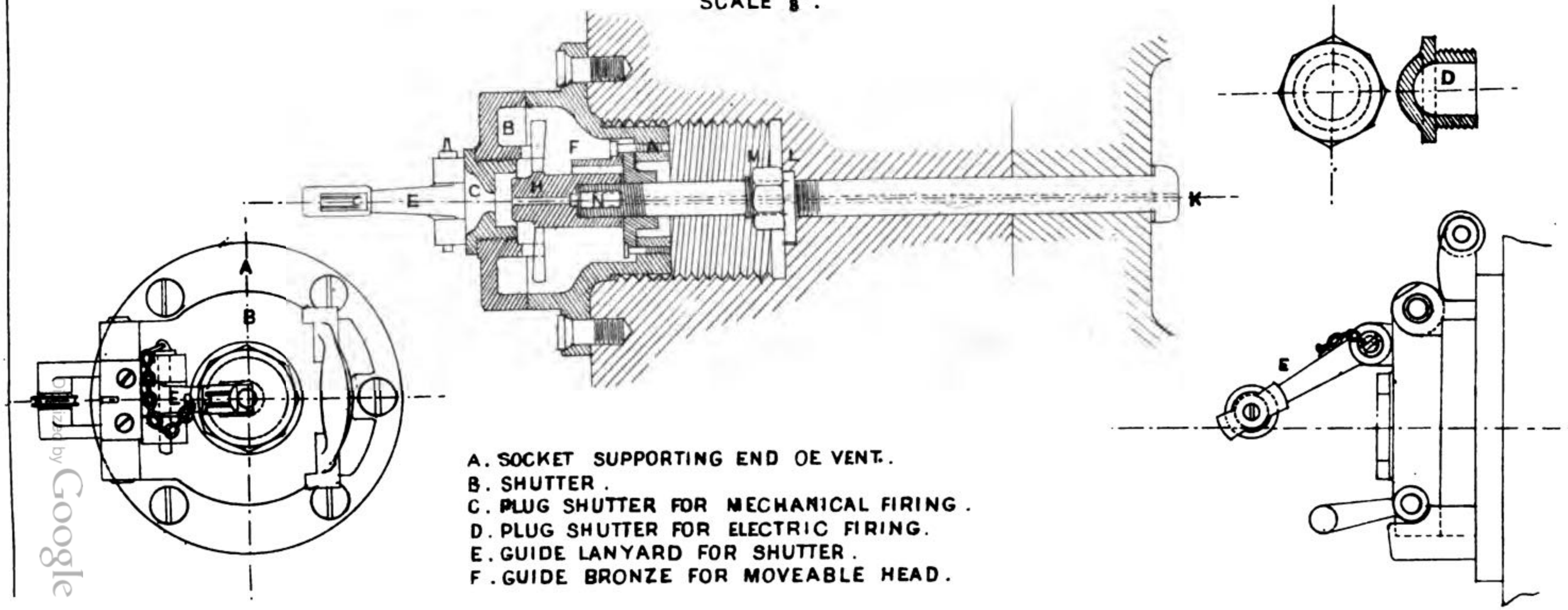
WITH ACORN GUIDE (A)

SCALE $\frac{1}{32}$



12·5 INCH OF 38 TONS MARK II. AXIAL VENT WITH SHUTTER &c.

SCALE $\frac{1}{8}$.



A. SOCKET SUPPORTING END OE VENT.
B. SHUTTER.
C. PLUG SHUTTER FOR MECHANICAL FIRING.
D. PLUG SHUTTER FOR ELECTRIC FIRING.
E. GUIDE LANYARD FOR SHUTTER.
F. GUIDE BRONZE FOR MOVEABLE HEAD.

DANGERFIELD, LITH. 22, BEDFORD ST. COVENT GARDEN. 7373.

	9-prs. of 8 Cwt. Mark I. L.S.	9-prs. of 8 Cwt. Mark II. S.S.	9-prs. of 6 Cwt. Mark I. S.S.	9-prs. of 6 Cwt. Mark II. L.S.	9-prs. of 6 Cwt. Mark III. S.S.	2·5″ Jointed of 400 lb.	7-prs. Mark IV of 200 lb. L.S.	7-prs. Mark IV of 200 lb. S.S.	Howitzers. 8″ of 70 Cwt.	Howitzers. 8″ of 46 Cwt.	Howitzers. 6·6″ of 36 Cwt.	Howitzers. 6·3″ of 18 Cwt.	Remarks and Proportion of Spare Stores.
Bands, elevating (with bracket)	—	—	—	—	—	—	—	—	—	—	—	—	* For Mark II guns only, when mounted on H.M.S. "Ajax" and "Agamemnon."
Bar, shifting	—	—	—	—	—	1	—	—	—	—	—	—	
Bearers { shot and shell ...	—	—	—	—	—	—	—	—	1	1	1	—	
Bearers { wood, breech lifting	—	—	—	—	—	—	1	—	—	—	—	—	
Bits, vent { 29-inch	—	—	—	—	—	—	—	—	—	—	—	—	
Bits, vent { 23 ,, ...	—	—	—	—	—	—	—	—	—	—	—	—	
Bits, vent { 17 ,, ...	—	—	—	—	—	—	—	—	—	—	—	—	
Blocks { dismounting... ...	—	—	—	—	—	—	—	—	—	—	—	—	
Blocks { preserving, muzzle sight	—	—	—	—	—	1	—	—	—	—	—	—	
Bolt { cascable, elevating ...	—	—	—	—	—	—	—	—	—	—	—	—	
Bolt { vent	1	1	1	1	1	—	—	1	—	—	—	—	
Brackets { fore-sight, with 2 screws	—	—	—	—	—	—	—	—	—	—	—	—	
Brackets { elevating { complete	—	—	—	—	—	—	—	—	—	—	—	—	
Brackets { elevating { with stud complete	—	—	—	—	—	—	—	—	—	—	—	—	1 stud to 4 or less number of guns.
Brackets { fore sight, with 2 screws fixing	—	—	—	—	—	—	—	—	—	—	—	—	
Cascable, slinging, removable...	—	—	—	—	—	—	—	—	—	—	—	—	* Mark II guns only. 1 to each battery where these guns are mounted.
Clamps, tangent sight { A ...	—	—	—	—	—	—	—	—	—	—	—	—	
Clamps, tangent sight { B ...	—	—	—	—	—	—	—	—	—	—	—	—	
Clamps, tangent sight { C ...	—	—	—	—	—	—	—	—	2	—	2	2	* Special pattern for

Plate { elevating (with plate, bolt, washer, keep-pin, and screws, fixing)	—	—	—	—	—	—	—	—	—	—
Plate { trunnion	—	—	—	—	—	—	—	—	—	—
Screws, preserving { eye bolt	—	—	—	—	—	—	—	—	—	—
Screws, preserving { graduated bar for rocker	—	—	—	—	—	—	—	—	—	—
Screws, preserving { trunnion sight ...	—	—	—	—	—	—	—	—	—	—
Sights, R.M.L., reflecting, counterweight, carriage, Mark II { lower ...	—	—	—	—	—	—	—	—	—	—
Sights, R.M.L., reflecting, counterweight, carriage, Mark II { upper ...	—	—	—	—	—	—	—	—	—	—
Studs, trunnion	—	—	—	—	—	—	—	—	—	—
Small-port Carriages.										
Plates, elevating, complete { Mark II ...	—	—	—	1	—	—	—	—	—	—
Plates, elevating, complete { Mark III ...	—	—	—	—	—	—	—	—	—	—
Screws, preserving, plate, elevating ...	—	—	—	7	—	—	—	—	—	—
Sights, R.M.L., reflecting (chase) { fore ...	—	—	—	2	—	—	—	—	—	—
Sights, R.M.L., reflecting (chase) { hind	—	—	—	2	—	—	—	—	—	—
Studs, trunnion, with gudgeon	—	—	—	2	—	—	—	—	—	—
Over-bank Carriages.										
Plates, elevating, complete with bolt, pin, washer, and fixing screws { breech	—	—	—	—	—	—	—	—	—	—
Plates, elevating, complete with bolt, pin, washer, and fixing screws { muzzle	—	—	—	—	—	—	—	—	—	—
Screws, preserving, plate, elevating ...	—	—	—	—	—	—	—	—	—	—

r. of wt.	Converted R.M.L. Guns.							9-prs.					7-prs.			Howitzers.				
								of 8 Cwt.		of 6 Cwt.				Mark IV. of 200 lb.						Remarks and Proportion of Spare Stores.
S.S.	80-pr. of 5 Tons.	64-pr. of 71 Cwt.	64-pr. of 58 Cwt.	40-pr. of 34 and 35 Cwt.	25-pr. of 18 Cwt.	16-pr. of 12 Cwt.	13-pr. of 8 Cwt.	Mark I. L.S.	Mark II. S.S.	Mark I. S.S.	Mark II. L.S.	Mark III. S.S.	Jointed of 400 lb.	L.S.	S.S.	8″ of 70 Cwt.	8″ of 46 Cwt.	6·6″ of 36 Cwt.	6·3″ of 18 Cwt.	
—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	2	1	2	1	Fore-sights and tangent sights (except those belonging to field guns) are issued 1 to every 10 or less number of sights of the same nature.
—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	2	1	2	1	
—	—	—	1	—	—	2	—	—	—	—	—	—	2	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* Centre only. † Mark II only.
—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* Mark I only.
1†	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* Sides only. † Centre only. ‡ Mark II only.
—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* Sides only.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* Identical with tangent sight.
—	—	—	1	—	—	—	1	1	1	1	1	1	—	1	1	—	—	—	—	1 glass mirror of each nature per gun, and 1 mirror with frame, &c., complete to every 10 or less number of guns.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
2	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* H.M.S. "Glatton."
2	—	2*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* Naval only.
—	2	2*	—	2	2	2	2†	2†	2†	2†	2†	2†	2	2†	2†	—	—	—	—	* Land only. † 1 long and 1 short.
1	—	—	1*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* Special B.
—	—	—	—	—	—	—	1	1	1	1	1	1	—	1	1	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* 7″ 6½ ton Mark I only.
—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* Except 6½ ton Mark I.
—	—	—	1	1*	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	* Mark I only.
—	—	—	—	1*	1	1	—	—	—	—	—	—	—	—	—	—	—	1	1	* Mark II only.
—	—	—	—	—	—	—	1	1	1	1	1	1	1	1	1	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 per fort or turret.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 to every gun.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* For Mark II guns only.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
1	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	1	1	1	1	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
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—	—	—	1	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	
1	—	1	—	—	—	—	—	—	1	1	—	1	—	—	—	—	—	—	—	
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R

PART II.

CHAPTER IV.

RIFLED MUZZLE-LOADING GUNS.

Remarks on R.M.L. guns.—Designation.—Classes of ordnance.—L.S. and S.S. guns.—Bronze and steel 7-pr. guns.—7-pr. jointed gun.—9-pr. guns for land and sea service.—13-pr. gun.—16-pr. gun.—25-pr. gun.—40-pr. gun.—64-pr. guns with steel and wrought-iron barrels.—Different dimensions of the coned end of the bore.—6·6-in gun.—Special sights.—7-inch of 7 tons, 6½ tons, and 90 cwt. —8-inch guns.—9-inch guns.—10- and 11-inch guns.—12-inch of 25 and 35 tons. —12·5-inch.—Axial vents.—Special guns for the "Ajax," "Agamemnon," &c.— 80-ton guns.—100-ton guns.—Table of dimensions, rifling, &c.—Table of ballistic effects.

THE general construction of R.M.L. guns has been fully explained, but there are differences in dimensions, sights, fittings, and stores associated with every nature of gun which must now be pointed out in detail. **R.M.L. guns.**

As regards the designation of R.M.L. guns, all having a calibre of 6·6 inches and upwards, are known by their calibre in inches; smaller natures, with the one exception of the 2·5-inch gun, are named by the weight of their shell. They are all called "ordnance, wrought-iron" except those which are made entirely of bronze or steel: even guns in which there is a preponderance of steel are included under this designation in returns and vocabulary books. **Designation.**

R.M.L. guns may be classified according to the service for which they are destined in the following manner:— **Classes of guns.**

(1) Mountain or Boat Guns.
2·5-inch 7-prs. of every description.

(2) Field, Boat, or Field Marine.
9, 13, and 16-pr. guns.

(3) Siege or Position.
25 and 40-pr. guns, and the 6·6-inch gun.
All the howitzers are associated with this class.*

* A unit of siege train consists of sixteen pieces of ordnance, which may be light, medium, or heavy, as required for the operations in view. Six 7-pr. guns may also be associated with any unit for operations in advanced trenches. The nature and number of each kind of ordnance comprised in a unit are as follows:—

Light unit	25-prs.	8
	6·3-inch howitzers	8
Medium unit	40-prs. Mark II	6
	6·6-inch howitzers	10
Heavy unit	6·6-inch guns	2
	40-prs., Mark II	4
	8-inch howitzer, 70 cwt.	10

(4) Medium.
64-pr. guns of all kinds; the 7-inch of 90 cwt.; and all the "Converted" R.M.L. guns.

(5) Heavy.
7-inch of 6½ tons and all guns of larger calibre up to guns of 100 tons weight.

L.S. and S.S.

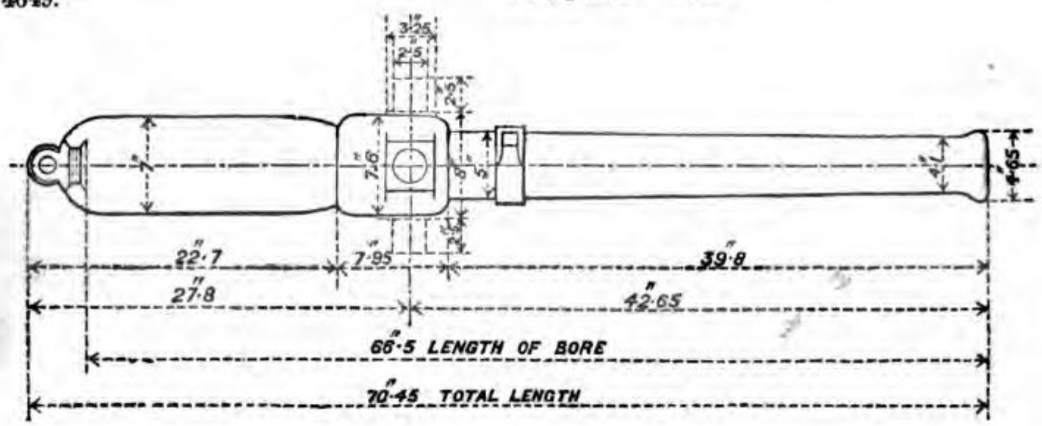
A distinction is made between guns appropriated for land or sea service; a few natures are entirely set apart in this way for one branch of the service, but generally the difference only consists in special fittings and separation between War Office and Admiralty charge.

In describing each nature of gun, with its distinctive features and details, it will be convenient to take the series in order from the lightest to the heaviest piece.

2·5-inch steel, 400 lb. §§ 3797, 4649.

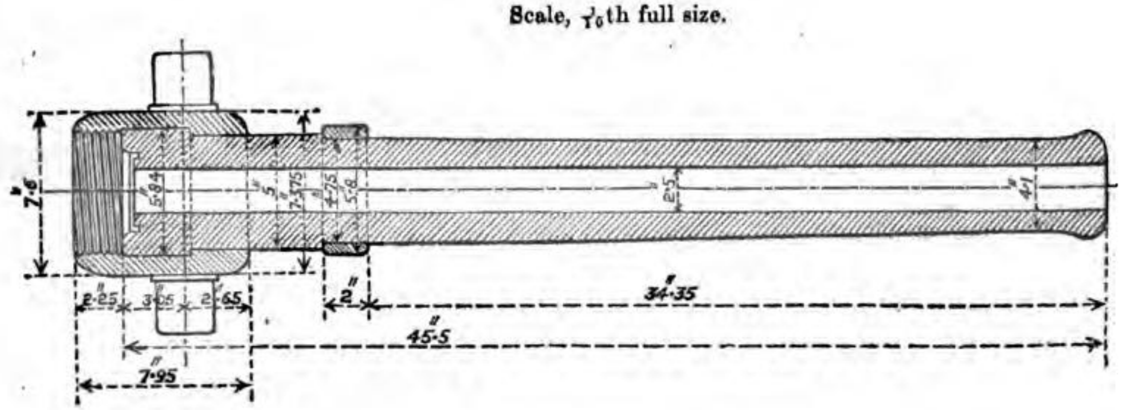
ORDNANCE, STEEL, R.M.L., 2·5-INCH.

Scale, ¾-inch = 1 foot.



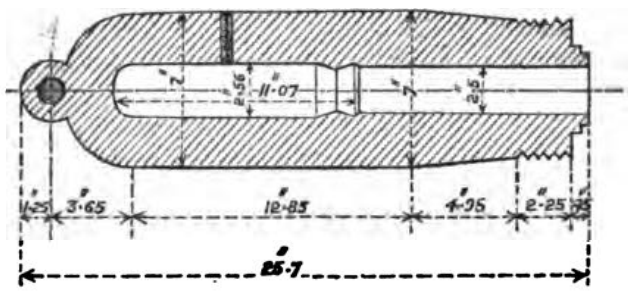
MUZZLE PORTION.

Scale, $\frac{1}{10}$th full size.



The special stores connected with this gun will be found in Table XX, p. 172.

BREECH PORTION.



Twelve guns of this description, which were made by the Elswick Ordnance Company according to designs suggested by Colonel Le Mesurier, R.A., were despatched to Afghanistan in 1879;* these proved satisfactory on active service, so the principle was adopted for a similar gun designed in the Royal Gun Factory, of which a large number have now been manufactured.

The gun consists of two parts, the breech and the muzzle portions each weighing about 200 lb., which is considered a maximum load for a mule's burden. The breech portion is arranged to contain the entire charge; it is formed out of a solid block of steel, the front end being furnished with a screw-thread to receive the junction nut. The muzzle portion consists of the steel chase and a wrought-iron ring which is provided with trunnions. This ring in future will be made of steel. The trunnion piece cannot be removed from the chase on account of a sight ring, which is permanently attached in a position to allow sufficient play for this the junction nut. The two parts of the gun are united by means of this trunnion ring in conjunction with a spigot and faucet joint. A steel gas ring is also introduced in the joint to prevent any escape. A key or feather on the muzzle portion fits into a recess in the breech portion, to ensure the two parts coming together correctly. When placed in position the union is effected by turning the junction nut in the direction which is indicated by an arrow and the word "Tighten" on the right trunnion until a line on the latter accords with a similar line on the top of the breech; a few moderate blows with a hammer will suffice to ensure this, but a trunnion-block must be used to protect the trunnion itself from injury when receiving the blows.

The calibre of this gun is only 2·5 inches. The vent is situated vertically 5·25 inches from the end of the bore. There is a powder chamber of slightly greater diameter than that of the bore, and there is a contraction or choke at the entrance which ensures the projectile being always rammed home to a definite point. The capacity of the chamber is 54 cubic inches.

The rifling, which is 54·73 inches in length, consists of 8 grooves of Maitland muzzle-loading type, ·05 of an inch deep; with a twist increasing from 1 turn in 80 cals. to 1 in 30 at 3·53 inches from the muzzle, the remainder being uniform of that pitch.

* These guns never passed through the R.G.F., even for examination or proof. They differ in many details from the service gun of this kind. The idea of a gun in two parts apparently had its origin in Russia, having been proposed in 1876 by Captain Kolokolzor, Director of the Manufactory at Obuchow. See "La Guerre d'Orient," translated by Captain Walford, R.A., in the papers of the R.A. Institution, 1883.

CHAP. IV.

The gun is provided with two sets of sights; the tangent scales drop into sockets formed in projections of solid steel on the breech, and they are furnished with special moveable clamps; the fore-sights are removeable, attached to the sight ring by a combination of the screw and drop systems. These sights can be used for rough or fine laying. The angle of correction for drift is 1 degree.

7-pr. R.M.L. Guns.

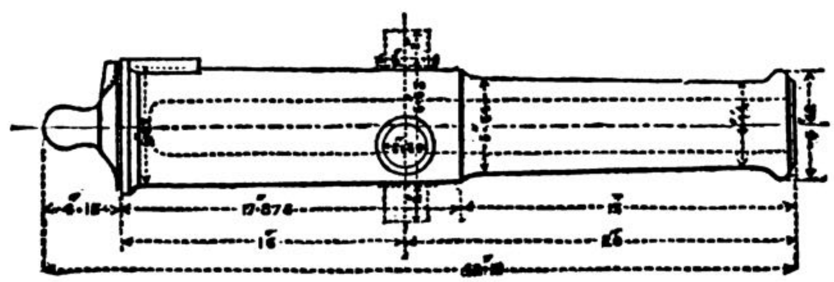
There are eight patterns of 7-pr. guns in the service, including the jointed gun. The three first Marks are made of bronze, being conversions of 3-pr. S.B. pieces into 7-pr. rifled guns. Their history may be given as follows:—

In 1865 some small rifled guns were required by the Indian Government to accompany the expedition to Bhootan. Steel guns were demanded, but as these could not be manufactured in time a few bronze

7-pr. bronze, Mark I. § 1146.

7-PR. BRONZE. MARK I. 224-LB. CALIBRE, INCHES.

Scale, 1 inch = 1 foot

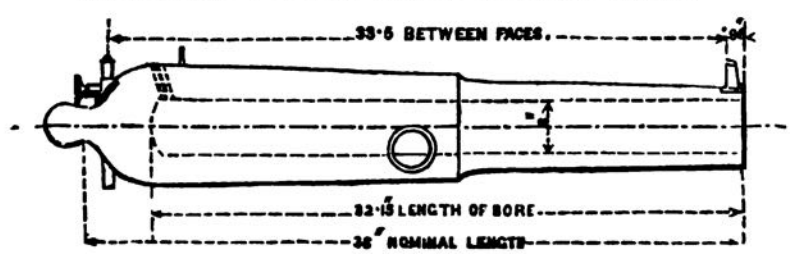


3-pr. S.B. guns of 2¼ cwt. were turned down to a weight of 224 lb., bored up to 3-inch calibre, and rifled on the French system with a twist of 1 turn in 20 calibres.

This gun was found to be too heavy for mules in a mountainous country, and a further reduction of weight to 200 lb. was suggested in the design known as Mark II, which was afterwards adopted.

7-pr. bronze, Mark II. § 1935.

7-PR. BRONZE. MARK II. 200 LB. CALIBRE, 3 INCHES.



The Mark II differs from Mark I in having the exterior turned perfectly plain and in being 2 inches shorter in the bore. In 1870 six of these were sent to Canada for the Red River Expedition, and the pattern being afterwards approved by the Admiralty it was definitely adopted for service; now, however, they are about to be withdrawn from the navy.

About 50 of these have been made, but the preponderance was not satisfactory, and in 1871 a better design was submitted.

7-pr. Bronze. Mark III. 200 *lb.*

Only two guns of this pattern have been manufactured, although as recently as 1883 some conversions on the previous design have been made to replace similar pieces on service. **7-pr. bronze, Mark III.**

In exterior dimensions the Mark III somewhat resembles Mark I, but the breech and muzzle are plain with the exception of a dispart left on the top of the latter to form a recess for the sight. The old vent is plugged up, and a new bush inserted perpendicularly at the end of the bore. Owing, however, to the superiority shown by steel guns which had already been manufactured, the Mark III bronze piece was never introduced into the service.

7-pr. Steel. Mark I. 190 *lb.*

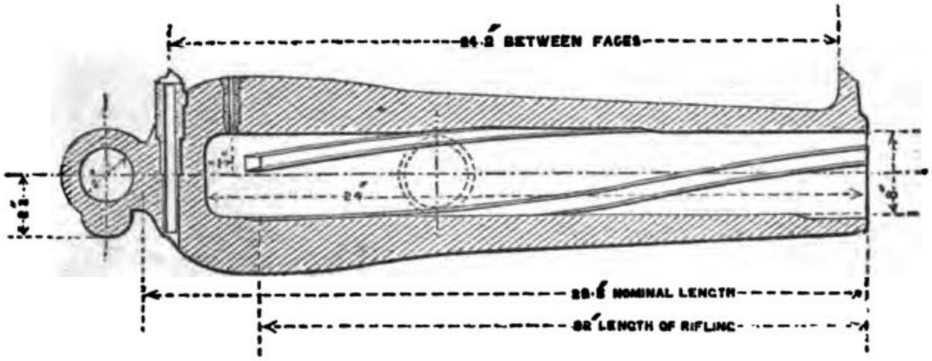
This was the first steel gun made for Bhootan in 1865. Five were sent out to India, but no more have been made on this pattern. These five, however, are still probably available for use in that country. **7-pr. steel, Mark I.**

7-pr. Steel. Mark II. 150 *lb.*

A few guns of this nature were sent to Abyssinia in 1867. Like the Mark I these were made out of a solid ingot of steel; they were sighted on the right side, the tangent sight working in a socket attached to the breech, and the fore-sight being screwed against the side of the muzzle. The cascable had a projection underneath, which fitted into a slot in the head of the elevating screw. Thirteen were manufactured, but a pattern was never sealed for the service. **7-pr. steel, Mark II. § 1506.**

7-PR. STEEL. MARK III. 150 LB.
CALIBRE, 3 INCHES.

7-pr. steel, Mark III. § 1717.



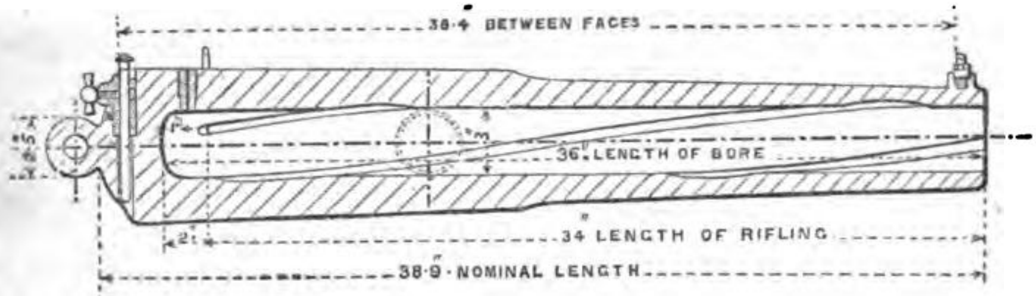
This gun differs from the Mark II only in being centre-sighted and in having a hole bored through the cascable, through which a rod can be passed to facilitate carriage and transport. The fore-sight is shaped out of the solid metal at the muzzle, and the hind-sight was a steel bar with plain head, but it is proposed that these sights should now be fitted with a deflection leaf.

In 1873 a more powerful gun was adopted as a Mark IV, and this is now generally used both for land and sea service. It is made out of a solid ingot of steel, and is half as long again in the bore as the gun **7-pr. steel, Mark IV. § 2498.**

CHAP. IV.

7-PR. STEEL. MARK IV. 200 LB.

CALIBRE, 3 INCHES.



of 150 lb. weight. The fore-sight is screwed into a small dispart patch at the muzzle, and two tangent scales are provided, one graduated to 6° which can be carried in the gun, and the other to 12° for long ranges.

All the foregoing natures of 7-pr. guns have the same calibre, viz.: 3 inches, and the "French" groove for the rifling, with a uniform twist of 1 turn in 20 calibres. They fire the same projectiles, but not all with the same charge. They are rear-vented (that is to say, the copper-bush is placed near the extremity of the bore) on account of firing very small charges. The bush is of exceptional pattern, being only 0·625 inch in diameter and having a fine screw on the exterior of 18 threads to the inch. The vent-channel, however, is of service diameter, viz.; 0·22 inch, to suit the common friction tubes. The sights are not interchangable.

9-pr. R.M.L. Guns.

There are five natures of 9-pr. muzzle-loading guns, two of which have been appropriated to "Land" and three to "Sea" service.

As regards their construction, they are all made of a steel barrel and wrought-iron jacket.

The calibre is 3 inches.

The rifling consists of 3 grooves, in section known as the "modified French," with a uniform twist of 1 turn in 30 calibres.

The guns are vented perpendicularly at the end of the bore, with a copper bush of universal diameter.

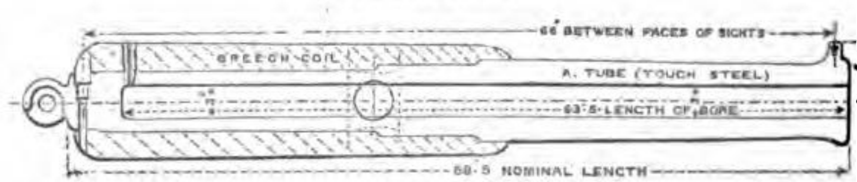
They are centre-sighted; and a second or long tangent scale is provided for extreme ranges: the shorter one only can be carried in the gun.

The changes in pattern are explained in the following historical sketch.

9-pr. 8 cwt., Mark I. § 2067.

9-PR. 8 CWT. MARK I.

CALIBRE, 3 INCHES.



The Mark I was adopted in 1871, to supersede the Armstrong

R.B.L. guns for field service, after experiments and trials which had extended over five or six years.

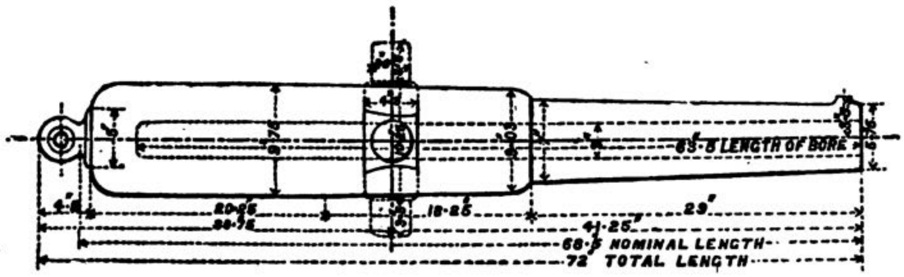
The fore-sight on this Mark of gun is a small screw hog-backed sight which is fixed in a dispart patch at the muzzle. The tangent sights are provided with deflection scales, the leaf being clamped with a thumbscrew.

In 1873 a gun of this kind was sealed to govern supplies for the navy, and designated the 9-pr. Mark II.

9-pr. 8 cwt., Mark II. § 2599.

9-PR. 8 CWT. MARK II.

CALIBRE, 3 INCHES.



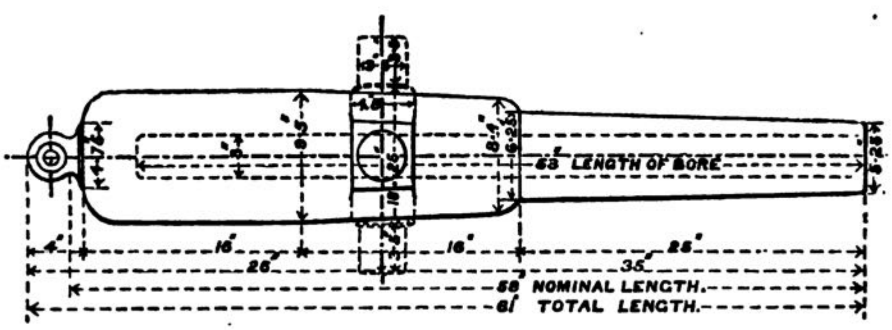
This differs from the Mark I chiefly in sighting; it has no swell at the muzzle, but there is a small dispart patch into which a pillar fore-sight is screwed, and the tangent sights are of S.S. pattern.*

A friction tube pin and guide plate are also affixed to the breech.

9-pr. 6 cwt Mark I. § 2674.

9-PR. 6 CWT. MARK I.

CALIBRES, 3 INCHES.



Designs for a shorter and lighter gun had been prepared in 1866, and a few had been made for experimental trials, but they had proved to be rather too short. However, it was decided in 1873 that some which were lying unfinished in store should then be completed for boat guns; at the same time it was never intended that any more of this pattern should be manufactured. Only 45 have been issued accordingly.

These guns differ from the heavier natures in being 10·5 inches shorter. They have no swell at the muzzle, and the fore-sight is a block of steel which is atrached to the gun by three fixing screws;

* The latest pattern is furnished with sliding leaf for deflection.

N 2

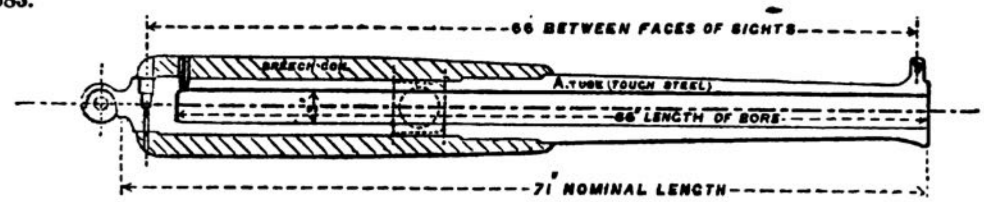
CHAP. IV. the tangent sights are of S.S. pattern, and hitherto they have been made with plain heads, but in the latest pattern a sliding leaf has been added for giving deflection.

Although the projectiles are the same for all 9-pr. guns, the charge for this nature is less than the charge for the others, on account of its shortness of bore; it is only $1\frac{1}{2}$ lb. R.L.G.² instead of $1\frac{3}{4}$ lb.; the M.V. is therefore about 150 f.s. less, and the power of this gun is inferior to that of all other 9-pr. R.M.L. guns.

9-pr. 6 cwt., Mark II. § 2683.

9-PR. 6 CWT. MARK II.

CALIBRE, 3 INCHES.



In 1874 a new gun of 6 cwt. was designed and adopted for the sake of mobility in the Royal Horse Artillery; this differs from the 8-cwt. gun chiefly in weight and dimensions: both guns fit the same carriage, are vented alike, have the same rifling, and take the same ammunition. The lighter gun is, however, the longer of the two, and with the same charge gives a little higher muzzle velocity.

§ 3962. In effecting this reduction of weight (amounting to one-fourth of the original weight of the piece) without any loss of power, the neck of the cascable was cut down rather too small. The apparent thickness also is very much reduced by a large slot underneath, which is cut into the metal to receive the head of the elevating screw. Several instances occurred of cracks starting from the angles of the slot after much firing, which arose from the jar on the elevating gear; in two cases the cascable was quite broken off. It was therefore decided in 1881 that the small cascables should be entirely removed, and stronger buttons of wrought iron screwed in instead. A few guns received strengthened cascables of steel, but this metal is not so suitable as iron. The material in each case is stamped on the new cascable.

The method of sighting is alike in both the L.S. guns, but the tangent sights are not interchangeable, as there is a difference in the radius to which the sight bars are graduated.

9-pr. 6 cwt. Mark III.

9-pr. 6 cwt., Mark III. In 1879 a few 9-pr. guns of 6 cwt. were required for sea service, and a small number of the Mark II guns were altered accordingly.

The alteration from the L.S. pattern consists in reducing the dispart patch without interfering with the swell at the muzzle, so that a screw fore-sight may be used with this gun.

The tangent scales are not interchangeable with those for either of the other S.S. 9-pr. guns.

S.S. fittings are supplied, and preserving screws which are always to be used when the fittings are not required on the gun.

These form a new series in which the numbers commence at 1001, to avoid confusion with the L.S. guns of the same nature and weight, which might otherwise bear the same numbers.

13-pr. R.M.L. Gun.

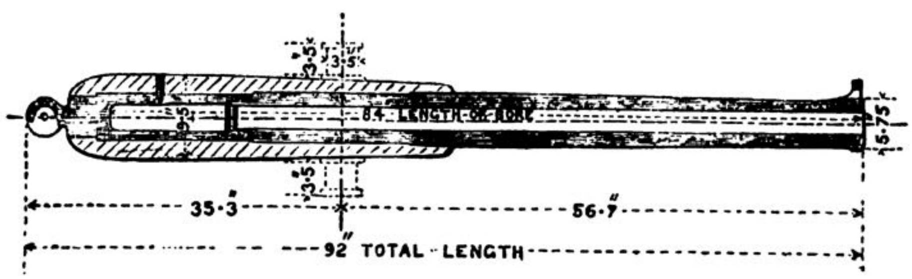
The manufacture of 13-pr. guns was commenced in 1879 and the

first pieces were completed as breech-loaders. Compared with the field guns of that time their power and accuracy of shooting was very remarkable, but breech-loading did not meet with approval. A considerable number of these guns, however, were ordered to be made, subject to completion as M.L. or B.L. when the question could be decided. It was subsequently ordered that they should be finished as muzzle-loading guns. CHAP. IV.

In general construction the Mark I 13-pr. resembles the 9- and 16-pr. guns, that is to say, it is built up of a steel barrel and wrought-iron jacket; but they differ in dimensions, and in almost every detail from the foregoing guns.

13-PR. 8 CWT. MARK I. 13-pr. 8 cwt., Mark I. § 4067.

CALIBRE, 3 INCHES.



Increased length is one of the principal features in the 13-pr. gun, the length of bore being 28 calibres. The calibre is 3 inches, and the powder chamber is slightly larger in diameter than the bore. There is a "choke" or contraction between the chamber and end of the rifling to prevent the projectiles from being rammed too far in the gun. The capacity of the chamber is 109 cubic inches.

This gun is forward-vented with a copper bush vertically situated about the middle of the chamber.

The rifling is polygroove and consists of 10 grooves of the Maitland muzzle-loading type, being half-an-inch wide and ·05 inch deep; with lands of the same width as the grooves. The twist increases from 1 turn in 100 calibres to 1 in 30 at a point 9 inches from the muzzle, the remainder being uniform at that pitch.

The guns are centre-sighted with special sights. The fore-sight is a gun-metal block, which fits into a recess in a dispart piece at the muzzle, having an acorn at the top for a rough line in laying, and cross wires in a window below. This sight should not be carried on the gun; a preserving block is supplied to take its place when the battery is not required for action. The hind-sight is a steel tangent bar with a cross frame to carry the leaf for deflection; the leaf has a movement of 1 degree right or left, and is traversed by means of a screw, which dispenses with the necessity for a clamp. It is furnished with the ordinary notch for rough laying, and an eye-hole to be used with the cross-wires.

13-pr. 8 cwt. Mark II.

The gun differs only in material from the Mark I, being made entirely of steel. Mark II. § 4635.

CHAP. IV.

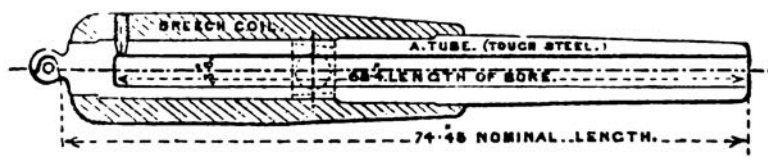
16-*pr. R.M.L. Gun.*

In 1870 experiments were made with R.M.L. guns of 3·3-inch and 3·6-inch calibre, with the view of providing a more powerful piece than the 9-pr. gun for some of the heavy field batteries. The latter calibre was adopted: and here it will be well to point out that in following the series of R.M.L. guns according to weight or calibre, chronological order cannot be preserved; the 13-pr. gun just described was a more modern piece by ten years than the 16-pr. R.M.L. gun.

16-pr. 12 cwt., Mark I. § 2221.

16-PR. 12 CWT. MARK I.

CALIBRE, 3·6 INCHES.



The construction, rifling, and position of the vent are the same in this as in 9-pr. guns; but the sighting is entirely different. The 16-pr. is sighted on both sides; the trunnion-sights are pillars of steel with hog-backed leaf screwed into the trunnion ring; and the tangent sights, which are graduated to the short radius, are fitted with slow-motion nuts for adjustment to one minute of elevation.

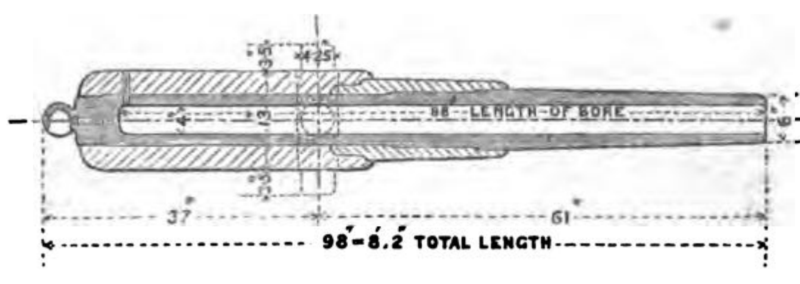
The hind-sights are clamped by means of copper set screws secured to the gun, and their removal is prevented by a pin screwed into the side of the breech.

The 16-pr. is a very short gun, for the length of bore is only 19 calibres. It is used for land service alone.

25-pr. 18 cwt., Mark I. § 2673.

25-*pr. R.M.L. Gun.*

The 25-pr. R.M.L. gun was proposed in 1871 as a gun of position and light siege piece, but its introduction into the service was not decided until 1874. There is only one Mark of this nature, and this has been issued for land service only.



In construction it resembles the 16-pr. gun, but owing to increase of length a B coil is introduced in front of the trunnions, and the jacket is shortened accordingly.

The calibre is 4 inches, and the bore is 22 calibres in length.

The rifling consists of three "Woolwich" grooves, with an uniform twist of 1 turn in 35 calibres.

The gun is rear-vented 1 inch from the end of the bore, with a copper bush perpendicular to the axis of the piece.

It is sighted on both sides; the trunnion sights are of the drop pattern, and the hind-sights are furnished with the slow-motion nut so as to read to every minute for elevation.

40-*pr. R.M.L. Guns.*

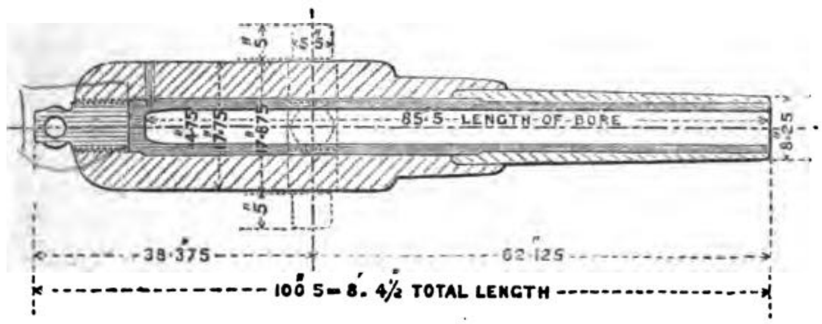
Separate cascable.

In 1871 it was decided to make 40-pr. muzzle-loading guns to supersede the B.L. screw guns of corresponding weight and calibre. There are two marks of this nature, which differ chiefly in length; they fire the same ammunition and fit the same carriage, but the longer gun gives higher velocity; it is therefore more powerful, and the sights and range tables are different.

40-pr. 34 cwt., Mark I. § 2478.

40-PR. 34 CWT. MARK I.

Scale, $\frac{1}{30}$.



This gun is built up of a solid-ended steel barrel, a B tube of coiled iron over the chase, a jacket, and cascable screwed in to support the end of the barrel. This is the first gun in the series in which the steel is not carried through to the cascable loop and in which the end of the bore is coned.

A gas channel is formed on the cascable screw for the gas to act as a tell-tale by its escape in the event of any failure of the A tube.

The calibre is 4·75 inches.

The rifling consists of three Woolwich grooves, with a uniform twist of 1 turn in 35 calibres.

The gun was rear-vented at first as shown in the figure, but all 40-prs. now passing through the Royal Gun Factory are revented in a forward position 7 inches from the end of the bore.

It is sighted on both sides like the 25-pr. gun.

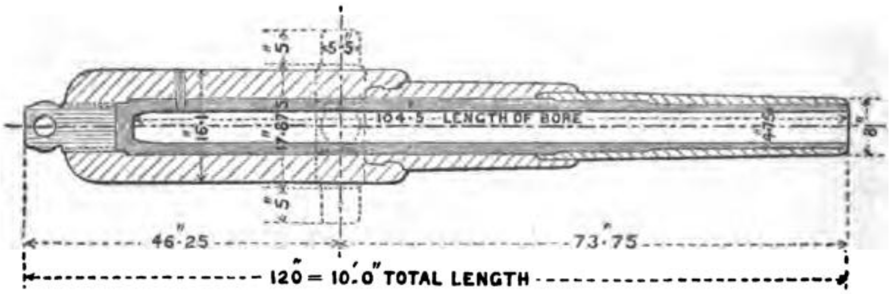
During the experiments carried on with the first of these guns there was some irregularity of shooting, which was attributed to incomplete combustion of the charge; a longer gun was therefore manufactured which gave more satisfactory results, and this design was approved in 1874 to supersede the Mark I, of which, however, twenty had already been made. These will be issued only to batteries of position.

CHAP. IV.

40-pr. 35 cwt., Mark II. § 2672.

40-PR. 35 CWT. MARK II.

Scale, .



The additional length of about 20 inches added only 1 cwt. to the nominal weight of the gun, because a reduction of thickness was effected at the same time over the breech. The length of bore was increased from 18 to 22 calibres.

The construction resembles that of Mark I, except that, on account of its length, a jacket and B coil were substituted (as in the 25-pr. gun) for the jacket alone. The rifling, position of vent, and the system of sighting remained the same as in the Mark I, but the tangent sights are not interchangeable on account of the different radius in sighting.*

The fore-sights, however, are common to both, and they are also interchangeable with those for the 25-pr. guns.

A new range table has been issued for the 40-pr. Mark II, which was rendered necessary by the development of muzzle velocity; this increase was due to the combined effect of a change in the powder, forward venting, and the adoption of gas-checks on the base of the shell.

64-*pr. R.M.L. Guns.*

The 64-pr. gun was the first muzzle-loading rifled piece introduced into the service. It was the heavy gun of its day, and superseded the B.L. wedge gun of about the same weight and also the 7-inch R.B.L. gun. In point of fact the first guns of this nature were built for breech-loaders and intended for 64-pr. wedge guns; a large number had been completed in this way, and some had been issued to the navy; but these were soon withdrawn from the service, and recently the whole class of wedge guns have been removed from the list of artillery. Orders have now been given for the wedge guns to be broken up whenever the material is required.

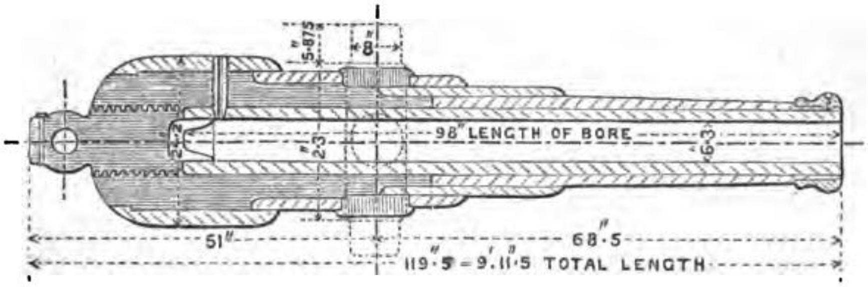
The adoption of muzzle-loading guns was decided upon in 1864 after years of experiment and trial, and the calibre of 6·3 inches was chosen that these guns might be able to fire 32-pr. spherical shot. The 64-pr. gun has since passed through three changes of pattern and various alterations besides, which might well have constituted additional marks of the gun.

* The 25- and 40-prs. fitted for siege train have cross-bar sights (fitted to one side only); they are set at the angle of drift so the deflection scale is not longer one side than the other.

64-PR. 64 CWT. MARK I.

CALIBRE, 6·3 INCHES.

64-pr. 64 cwt Mark I. § 1062.



The construction of this gun is of the Armstrong or original type, viz.: a barrel of coiled iron, a forged breech-piece, a B tube with muzzle-piece for the swell, four external thin coils, a trunnion ring of forged iron, and a cascable screwed into the breech to support a copper cup, which closes the end of the bore.

There was no gas escape in the earliest guns of this nature; it was introduced after a certain number had been made, and then it was placed *under* the cascable.

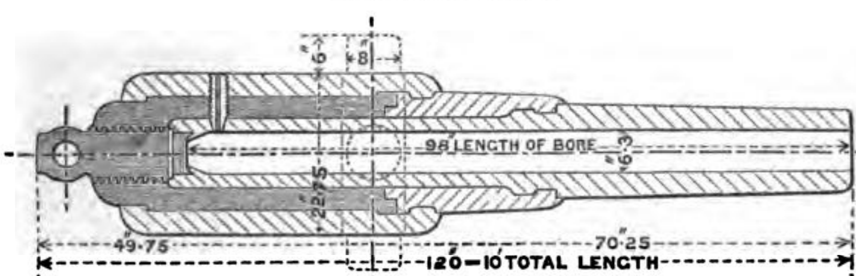
The guns are both side and centre-sighted, with an angle of correction for drift of 2° 16′. All heavier guns, with very few exceptions, are in like manner provided with three sets of sights.

The rifling at first was the "Shunt" groove with an uniform twist of 1 turn in 40 calibres. This form of groove was applied to all marks of the 64-pr. guns in succession, and to larger experimental pieces as well, but in 1870 it was decided to abolish the shunt system, and the "plain" groove was adopted instead; this is simply the deep portion of the shunt, that the alteration might not affect the projectiles in use with these guns. It was ordered also that this change should be made § 1996. in all existing 64-pr. guns on being repaired with a new barrel, so the shunt system is gradually becoming extinct.

64-PR. 64 CWT. MARK II.

CALIBRE, 6·3 INCHES.

64-pr. 64 cwt., Mark II. § 1608.



Only a few guns of this pattern were made in the year 1866. It differs from the Mark I in being built up of fewer parts, in exterior shape, and in the end of the barrel being closed by a wrought-iron plug, a copper disc intervening between the plug and the cascable screw. The swell at the muzzle is abolished and the chase is formed by the barrel itself, which is made of double thickness until reinforced by a coil. The gun is cylindrical from the breech to the trunnions, and the trunnion ring is welded to the breech coil to give longitudinal strength. Hook joints

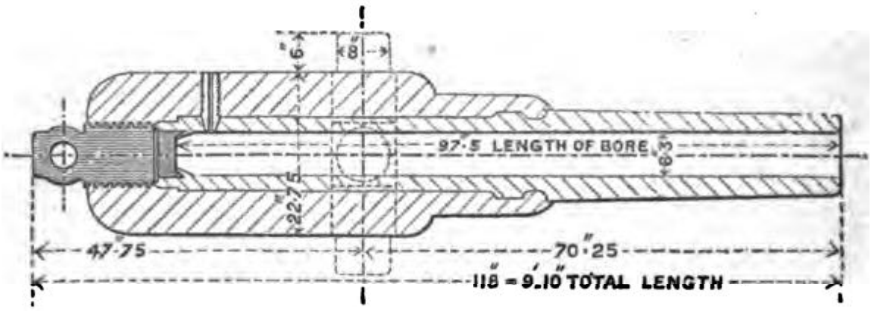
CHAP. IV. were also introduced for the same reason wherever the portions overlapped one another to "break joint" in the construction. These guns were marked with the letter B on the left trunnion at first, as an indication of pattern before the numerals were adopted as a general mode of distinction.

In rifling, sights, ammunition, &c., the Marks I and II 64-pr. guns are exactly alike.

64-pr. 64 cwt., Mark III. § 1608.

64-PR. 64 CWT. MARK III.

CALIBRE, 6·3 INCHES.



The manufacture of Mark III was commenced in 1867, in consequence of experiments which proved that this system of construction was stronger than that in which a forged breech-piece was used. The alteration mainly consisted in the adoption of a jacket of Fraser construction (with a triple coil over the breech), which comprised nearly all the exterior metal of the gun and covered about three-fifths of the length of the barrel.

In external appearance this gun resembles Mark II, but the breech is rounded off because there are no layers in the thickness of metal, which is all welded into one solid mass.

Guns of this pattern issued prior to March, 1868, have D stamped on the left trunnion; but this letter is removed as opportunity offers, and Mark III engraved in its stead.

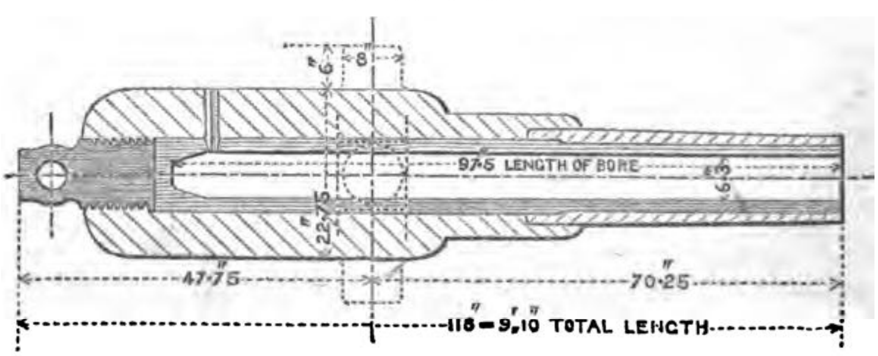
These Mark III guns, which have a wrought-iron barrel, were issued to the navy, but are now being withdrawn to be re-tubed with barrels of steel.

In 1871 solid-ended steel barrels were adopted in lieu of the coiled iron tubes, and a B tube of coiled iron was shrunk over the chase. This change in construction, however, did not constitute a new mark of gun

64-pr. 64 cwt., Mark III, with steel barrel.

64-PR. 64 CWT. MARK III.

WITH STEEL BARREL.



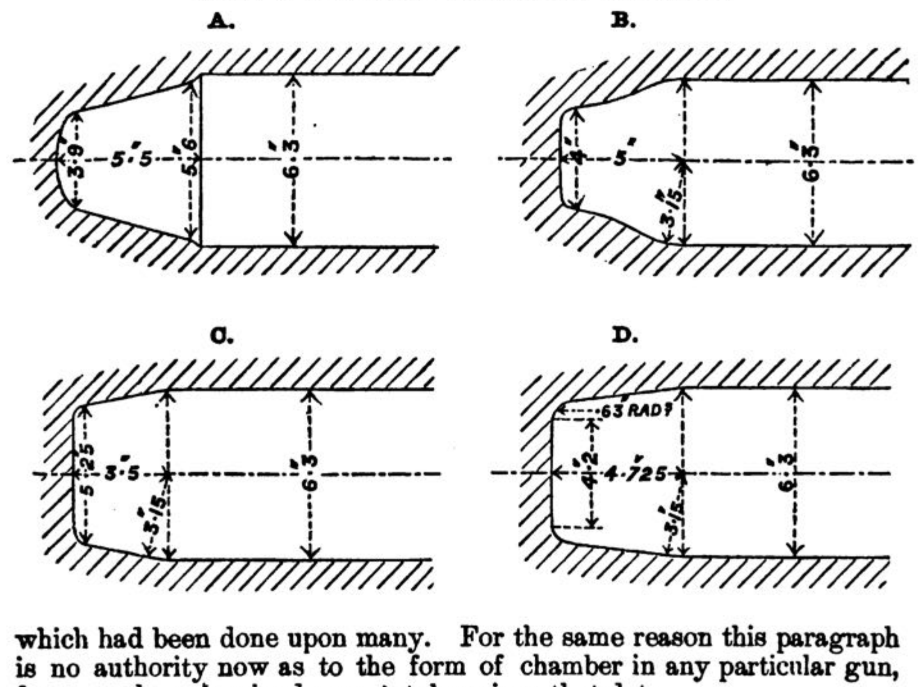
though the alteration led to an increase of strength with a consequent increase of charge both in powder and weight of the shell; the latter is now 90 lb., but it is still called a 64-pr. gun, and even the numeral remains as before. CHAP. IV.

The angle of sighting is 2° 50′ for these, but 2° 16′ in all other 64-pr. guns. The shunt groove will not be found in a steel barrel.

With change of design a slight difference was made in the dimensions of the cone at the end of the bore, and this point has been complicated further by the repair of many guns with a new A tube, an operation which was always carried out according to the latest method approved, and not according to the Mark of the gun. In 1880 it became necessary to affix some distinctive mark on these guns to indicate the form of the chamber and to govern the distribution of sponges; so an order was given to have the letters A, B, C, or D stamped on the face of the muzzle. The illustration below will show the varieties of form and the dimensions in each case at the end of the bore.

A paragraph in the "List of Changes in War Stores" was published § 3718.
to govern the execution of this work by local artificers (see § 3718). In these instructions not only was the work fully explained, but all the register numbers of the guns were clearly set forth in groups according to the letter which was to be engraved upon each. The numeral or mark was not a sufficient guide for this work, because of the repairs

64-PR. WROUGHT-IRON RIFLED GUNS OF 64 CWT.



which had been done upon many. For the same reason this paragraph is no authority now as to the form of chamber in any particular gun, for many have received new A tubes since that date.

Marks I and II are repaired with coiled iron barrels, with a coned end of the C form; all Mark III guns are re-tubed with steel, and these have the D form of chamber; consequently, the A and B chambers are gradually being abolished.*

It is probable that 64-pr. guns for S.S. will in future be prepared for the reception of a steel removable suit bush, a description of which and instructions for its use will be found at page 346.

* By a recent order the Marks I and II are not to be repaired in future.

CHAP. IV.

6.6-*inch R.M.L. Gun.*

This is a modification of the 64-pr. gun of 64 cwt., and was originally intended to be a conversion only; but with the exception of experimental pieces these guns have all been made entirely new.

The alteration which was carried out at first in a few 64-pr. guns consisted in boring out the metal to the full depth of the grooves ($\frac{3}{10}$ths of an inch), and in re-rifling the piece on a polygroove system with a calibre of 6·6 inches. The strength of the gun was not reduced to any appreciable extent by this change, for the slight reduction of thickness was balanced by the advantage of the polygroove rifling, which distributes the work done by the metal more equally all round the bore.

The new calibre enabled the gun to fire a shell of greater capacity, so the power of the piece was increased. It was also intended that the 6·6-inch R.M.L. gun should be associated with the 6·6-inch R.M.L. howitzer, in which case the ammunition for these two pieces of ordnance would become interchangeable.

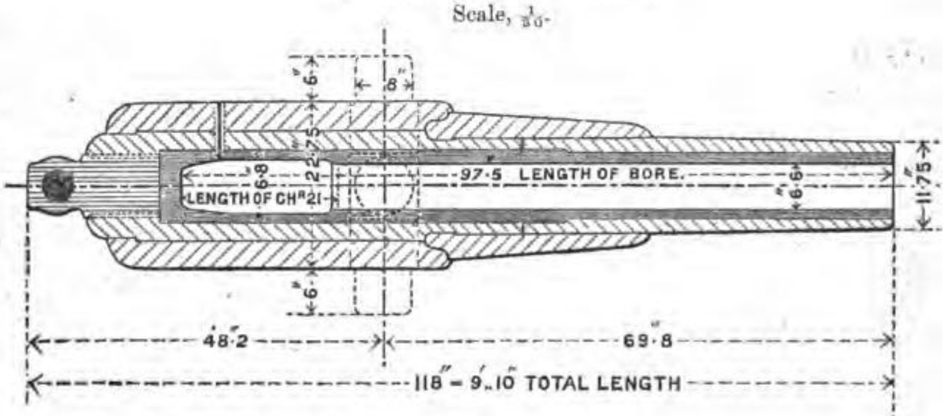
Conversion, however, was not a success, and it was therefore decided that new guns should be made; at the same time the weight was increased to 70 cwt. These guns will now be used in a heavy unit of siege train; and it is also intended that some shall be mounted in forts.

The gun is built up with an A tube of steel, forged and tempered in oil; a breech-piece and B tube of coiled iron which form the second layer of metal; a C coil in front of the trunnions which covers the joint; and a jacket consisting of a D coil and forged trunnion ring welded together; a cascable is also screwed into the breech to support the end of the barrel.

6·6-inch 70 cwt., Mark I. § 4373.

6·6-INCH. 70 CWT. MARK I.

Scale, $\frac{1}{30}$.



The rifling consists of 20 grooves of the Maitland muzzle-loading type, with a twist increasing from 1 turn in 100 calibres at the breech, to 1 in 35 at a distance of 13·2 inches from the muzzle, the remainder being uniform at that pitch.

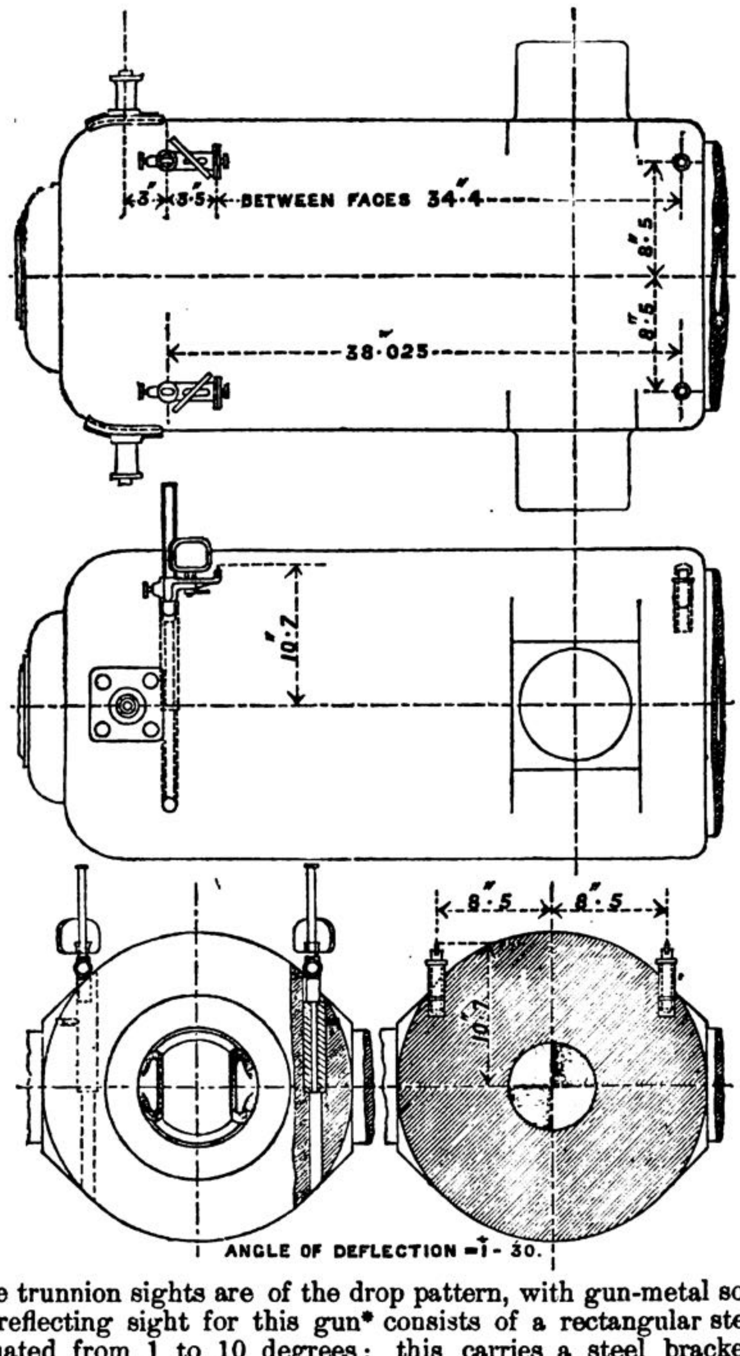
The grooves terminate abruptly 21 inches from the end of the bore, thus forming a stop for the projectile to regulate the density of the charge, and to prevent the shot from entering the chamber, which has a diameter of 6·8 inches, and a capacity of 707 cubic inches.

The gun is prepared for a hydro-pneumatic carriage (HP) by being fitted on either side with a pivot piece, and a trunnion plate with the necessary screws for attachment.

This gun is sighted on both sides, and is supplied with two kinds of

CHAP. IV.

tangent sights, viz.: one pair of special sights with reflectors, and two tangent sights of the ordinary service pattern (except that they have longer deflection scales) for direct laying; the sights fit into sockets on each side of the breech. A set of cross-bar sights is supplied to each gun also, as for the other siege guns (p. 186).



The trunnion sights are of the drop pattern, with gun-metal sockets.

A reflecting sight for this gun* consists of a rectangular steel bar graduated from 1 to 10 degrees: this carries a steel bracket, the direction of which is parallel to the axis of the gun, to be clamped at the desired elevation by a screw. Upon the muzzle end of the sliding bracket is a sight leaf with a notch, which can be moved laterally on a deflection scale to the extent of 1¼ degrees right or left. A mirror

* Identical in arrangement with the chase sights, p 159.

CHAP. IV. is pivoted on the sliding bracket between the sight leaf and the bar, and revolves round an axis at right angles to the bracket; it can be set at any angle to suit convenience in laying.

7-inch R.M.L. Guns.

There are three distinct natures of 7-inch guns, and two out of the three have passed through several changes in pattern. Internally they are all exactly alike except in length of bore, and they fire the same natures of projectiles, but with varying charge.

The rifling consists of three grooves of "Woolwich" form, with an uniform twist of 1 turn in 35 calibres.

They are all radially vented with a copper bush set at a distance of 8·5 inches from the end of the bore, which was estimated to be four-tenths the length of the cartridge.

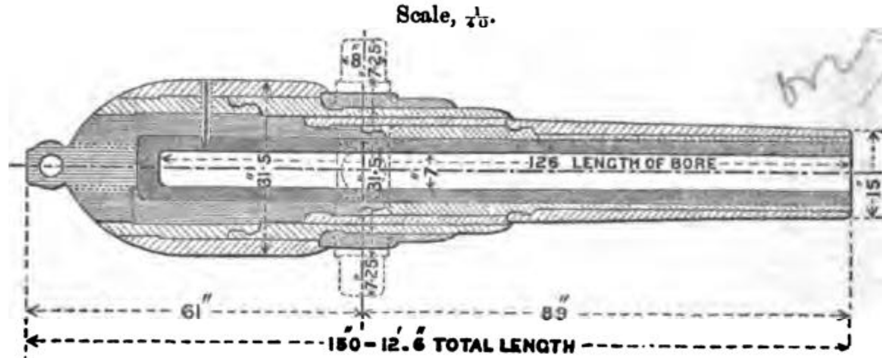
They are all side and centre-sighted, and the sights for the two heavier natures were at first interchangeable, for the radius distance and tangent scales are alike; but when the yards and fuze scales were added the sights became different, and each nature of gun now has its own.

The first in historical order is the 7-inch of 7 tons, and there are four marks of this weight. It has been issued to land service only.

7-inch, 7 tons, Mark I. § 1230.

7-INCH. 7 TONS. MARK I.

Scale, $\frac{1}{40}$.



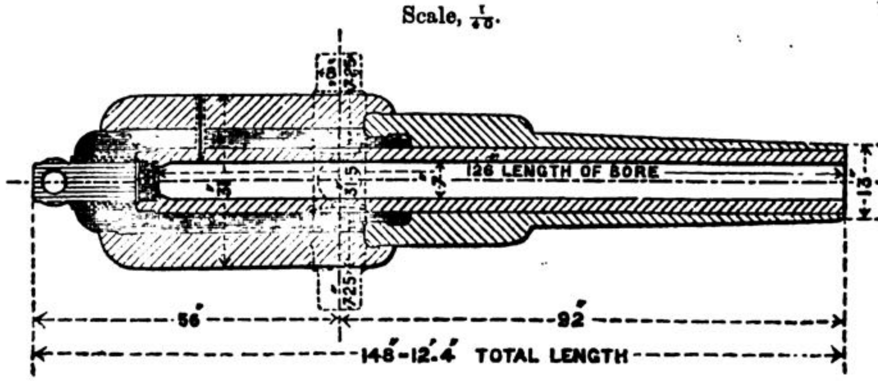
Mark I was approved in 1865 as a battering gun, to replace the 7-inch B.L. screw gun for land service. It is built on the Armstrong or original system of construction, and can be recognised by its external form. The end of the bore is cylindrical. A gas escape channel is cut perpendicularly through the breech-piece from the end of the barrel, and thence to the outside of the gun underneath the cascable loop.

A large number of these guns have been made.

7-inch, 7 tons, Mark II. § 1607.

7-INCH. 7 TONS. MARK II.

Scale, $\frac{1}{40}$.



A few of this pattern were made in 1867. The construction is that known as the "*modified*" system, being a link between the Armstrong and Fraser methods of manufacture. The guns consist of a coiled iron barrel which is closed at the breech-end with a wrought-iron plug, a forged breech-piece, a B-tube, which is made of a thick and thin portion united together, a jacket, and cascable screw.

The end of the bore is slightly coned to suit the adjustment of the wrought-iron plug according to the method known as the "Elswick loose end." The plug is fitted into the end of the barrel with an undercut seat, and supported by the cascable screw, a disc of copper intervening to ensure uniform support and tight fit.

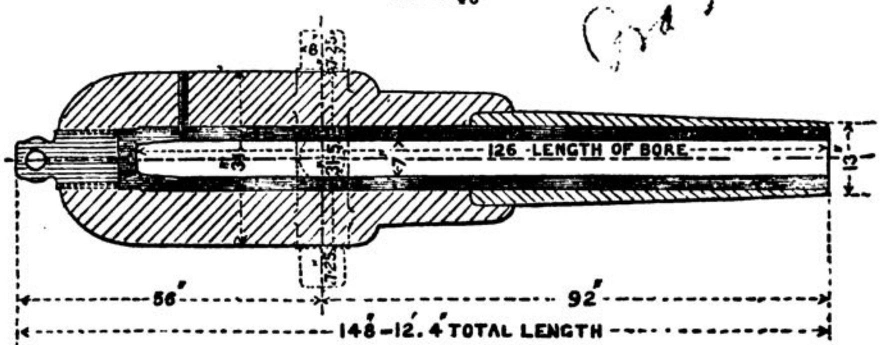
These guns were marked F I on the left trunnion; but since March, 1868, the designation has been changed to Mark II.*

Guns passing through the department have the letter removed, and the numeral stamped on instead. If repaired with a new A-tube, they are now fitted with a solid-ended barrel of steel.†

7-inch, 7 tons, Mark III. § 1607.

7-INCH. 7 TONS. MARK III.

Scale $\frac{1}{40}$.



In 1868 the "Fraser" construction was approved for this gun, together with an A-tube of steel; these were stamped F II on the trunnion, until the designation was changed to Mark III.

The chief alterations (as compared with Mark II) consisted in doing away with the breech-piece; in forming a triple breech coil by the process of winding bar upon bar; and in welding the whole mass of exterior metal together (excepting the thin portion of the tube over the muzzle and chase) in the form of a jacket. The B-tube was remodelled; for the thick part was embodied in the jacket, and the thin portion only remained to be shrunk on as a separate part of the gun, retaining the name of "B-tube."

The conical form at the end of the bore was somewhat extended to furnish sufficient thickness of steel at the point where a shoulder was formed on the outside of the barrel; this shoulder was intended to take part of the longitudinal thrust by throwing more work on the solid part of the jacket and less on the threads of the cascable screw.

The manufacture of 7-inch guns then ceased for a time, but it was resumed in 1878, when a pattern was sealed as Mark IV; a large number had been made of Mark III.

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* This marking was applied also to the 7-inch of 6½ tons of similar construction; and to the 8-inch and 9-inch R.M.L. guns. (See §§ 1462 and 1596.)

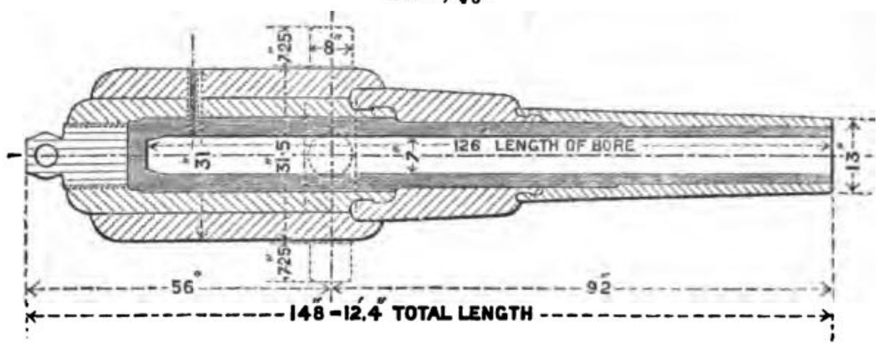
† All 7- and 8-inch guns with iron barrels are now to be withdrawn from the service.

CHAP. IV.

7-inch, 7 tons, Mark IV. § 3419.

7-INCH. 7 TONS. MARK IV.

Scale, $\frac{1}{40}$.

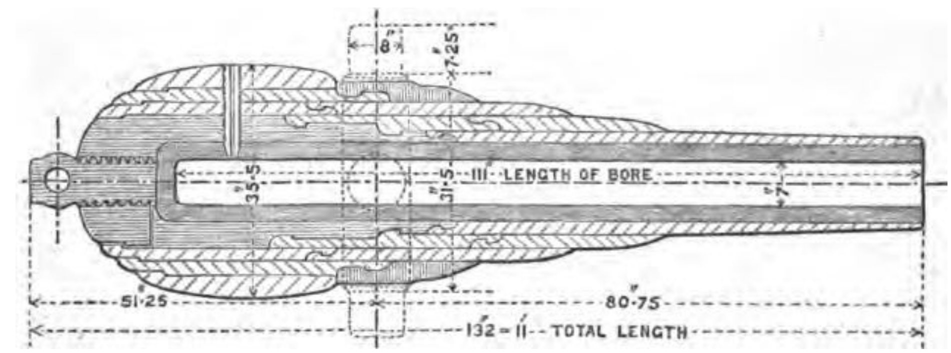


This differs from the Mark III only in construction, the dimensions being exactly the same. There is a slight increase of thickness in the steel tube at the breech end, and the Fraser jacket is divided into three parts, viz.: a breech-piece of coiled iron, a B-coil in front of the trunnions, and a jacket according to the R.G.F. system. By the re-introduction of a breech-piece among the parts of construction the outline becomes similar to that of the 7-inch Mark II; but it may be well to point out that the breech-piece in this case is coiled iron.

7-inch, 6½ tons, Mark I. § 1231.

7-INCH. 6½ TONS. MARK I.

Scale, $\frac{1}{32}$.

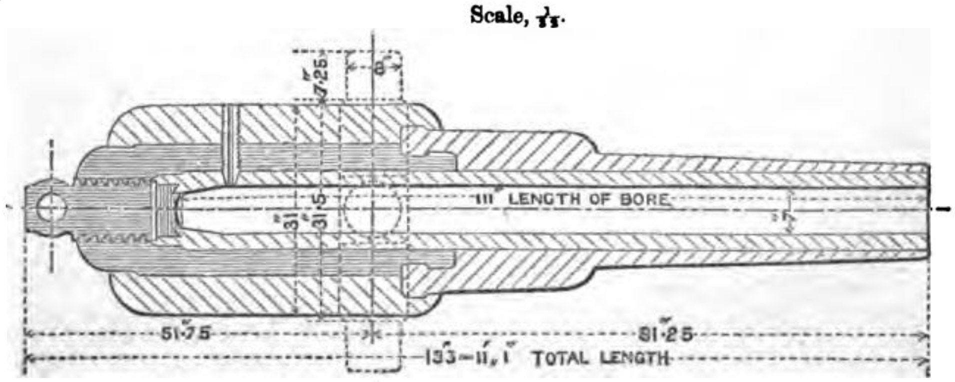


This gun was approved for S.S. in 1865, shortly after the introduction of 7-inch guns for L.S., being 12 inches shorter, and therefore more convenient for working on board ship, but a large number have been recently transferred to L.S. Its construction is much the same as that of the 7-inch of 7 tons Mark I. A heel-scale is engraved on the rear face of the cascable.

7-inch, 6½ tons, Mark II. § 1644.

7-INCH. 6½ TONS. MARK II.

Scale, $\frac{1}{32}$.

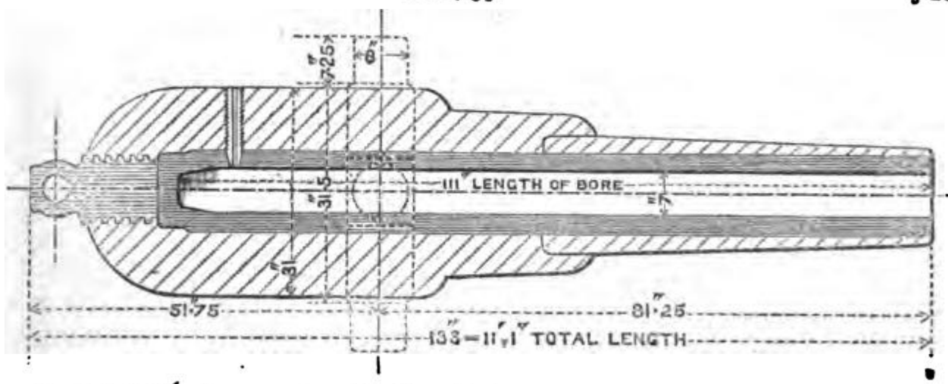


These were contemporary with the 7-inch Mark II of 7 tons, and were built up of the same number of parts; a few only were made, and these were stamped F I on the trunnion. They are now to be withdrawn from the service, as opportunity offers. CHAP. IV.

7-INCH. 6½ TONS. MARK III.

Scale, $\frac{1}{32}$.

7-inch 6½ tons, Mark III. § 1644.



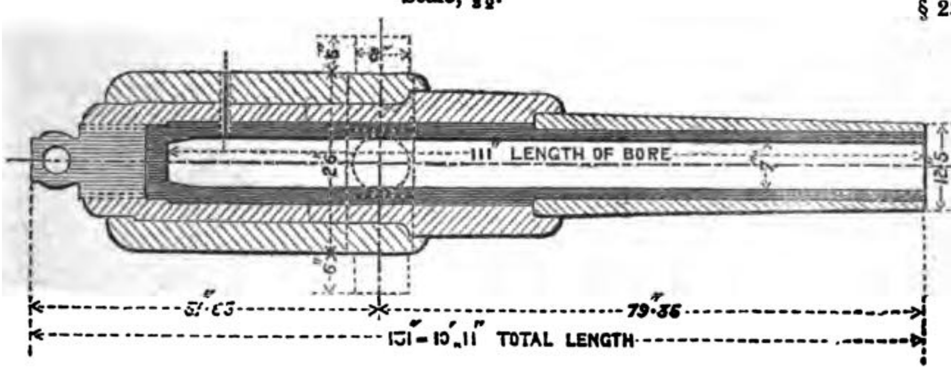
In 1868 the change already described as having taken place in construction was applied generally to all heavy guns; so the Mark III in this case exactly resembles the Mark III of 7-inch of 7 tons. They were all marked F II on the left trunnion at first.

The manufacture of S.S. guns of this weight, however, was soon discontinued, and no later pattern was introduced as in the case of the 7-inch land service guns: they were superseded altogether by heavier ordnance to pierce armour of increasing resistance, and some which had never been finished were reduced at the request of the Admiralty in 1874 by one-third of their weight to make broadside guns for unarmoured vessels.

7-INCH. 90 CWT. MARK I.

Scale, $\frac{1}{32}$.

7-inch, 90 cwt., Mark I. § 2363.



In this conversion the interior of the gun was unaltered, but the exterior was turned down all over and slightly shortened at the breech end. To regulate preponderance, however, it was necessary to make a new jacket, and therefore to turn off more metal than the mere difference of weight: the remainder of the old jacket was left to form a breech-piece.

A few new guns have been made of similar outline though not quite the same in design, which are included in the designation Mark I, but a large number of the service guns of 6½ tons have been reduced to this pattern.

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These guns do not fire a battering charge, consequently they differ in muzzle-velocity, sighting, and drift; the angle of sighting is only 44′ instead of 3°, as in all the other 7-inch guns.

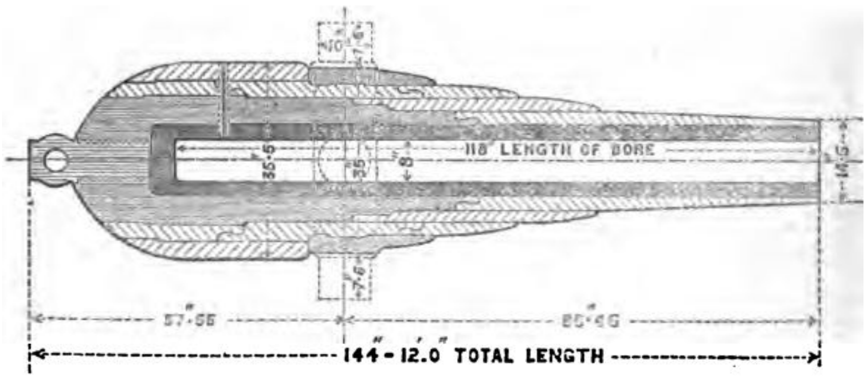
8-inch R.M.L. Guns.

There is only one nature of 8-inch, but this has passed through three changes of pattern. The construction in each case corresponds with the similar mark of the 7-inch guns of $6\frac{1}{2}$ or 7 tons weight.

8-inch, 9 tons, Mark I. § 1289.

8-INCH. 9 TONS. MARK I.

Scale, $\frac{1}{45}$.

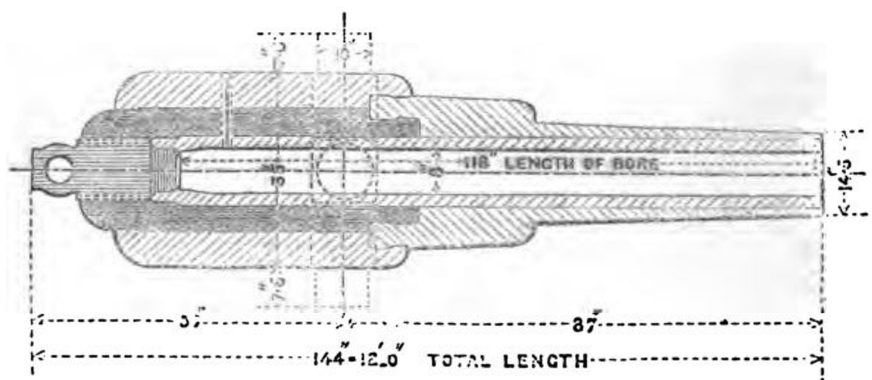


The first 8-inch guns were introduced for S.S. in 1866, but a few were afterwards issued to L.S.; altogether 76 of this mark have been made. The construction and different parts are shown in the accompanying drawing.

8-inch 9 tons, Mark II. § 1643.

8-INCH. 9 TONS. MARK II.

Scale, $\frac{1}{45}$.



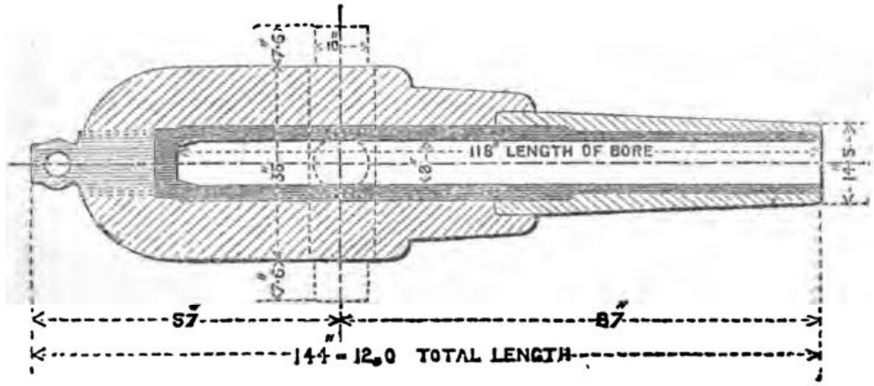
A few only of this pattern were made in 1867, when this mode of construction was adopted for all the heavy guns which happened to be under manufacture at the time. These have wrought-iron barrels closed with the Elswick loose end. The forged breech-piece was retained, but the dimensions were altered in front of the trunnions. They were marked F I. No pattern was sealed, and no separate description was given in the Changes of War Stores; they are only mentioned as an addendum to the paragraph relating to the 8-inch Mark III. These guns with wrought-iron tubes are now to be withdrawn from the service.

CHAP. IV.

8-INCH. 9 TONS. MARK III.

Scale, $\frac{1}{40}$.

8-inch 9 tons, Mark III. § 1643.



The Mark III was approved in 1868. These guns were built up on the "Fraser" system, and a few were marked F II at first. The dimensions are exactly the same as in the previous pattern.

The rifling in all the 8-inch R.M.L. guns consists of four "Woolwich" grooves with an increasing twist, which commences from zero and ends with one turn in 40 calibres at the muzzle. The change from uniform to increasing twist was rendered necessary by the weight of the shell, which are more than half as heavy again as those for 7-inch guns. For this reason increasing twist was applied to all larger guns, and a few years later the change was extended to all rifled ordnance without regard to calibre.

The sights are the same for all Marks of 8-inch, but there is a slight difference in their position, which affects only their height and their distance from the centre of the gun. For S.S. the rear face of the cascable was graduated with a heel-scale.

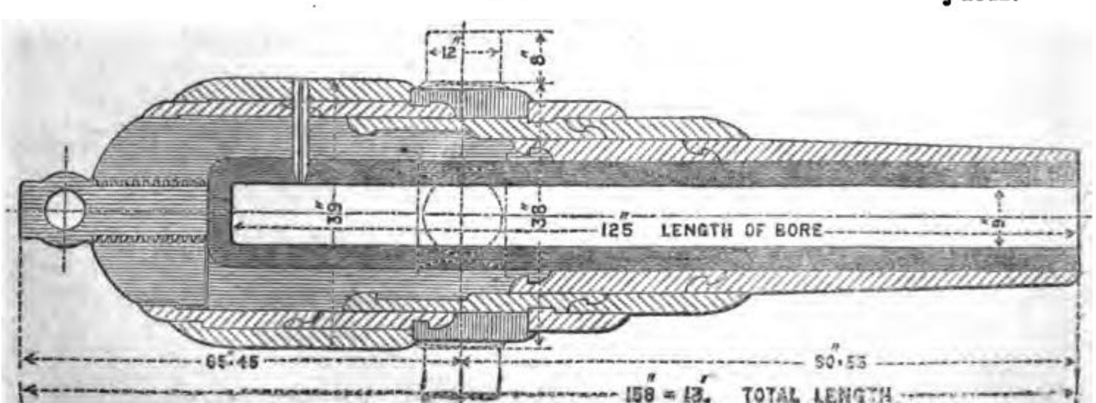
9-*inch R.M.L. Guns.*

There are no less than five Marks of this nature. The first three represent the Original, the Modified, and the Fraser construction as in the 7- and 8-inch; but a greater number of this calibre were made and further changes were introduced in the method of building them up.

9-INCH. 12 TONS. MARK I.

Scale, $\frac{1}{32}$.

9-inch 12 tons, Mark I. § 1642.



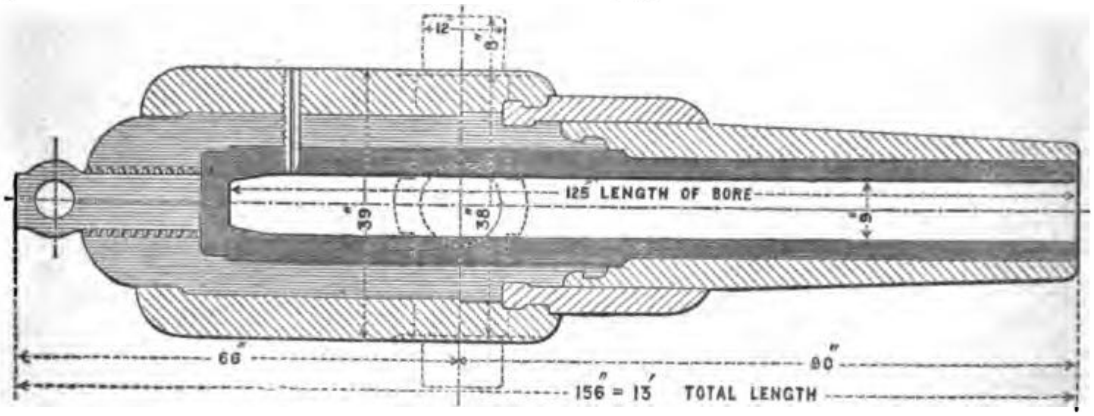
CHAP. IV.

The Mark I was designed in 1865 as a broadside gun for ironclad ships, and for the defence of harbours and sea-fronts; 190 were made. They may be easily recognised by their outline, and the number of grooves in the rifling, which in this calibre is six.*

9-inch, 12 tons Mark I. § 1642.

9-INCH. 12 TONS. MARK II.

Scale, $\frac{1}{32}$.

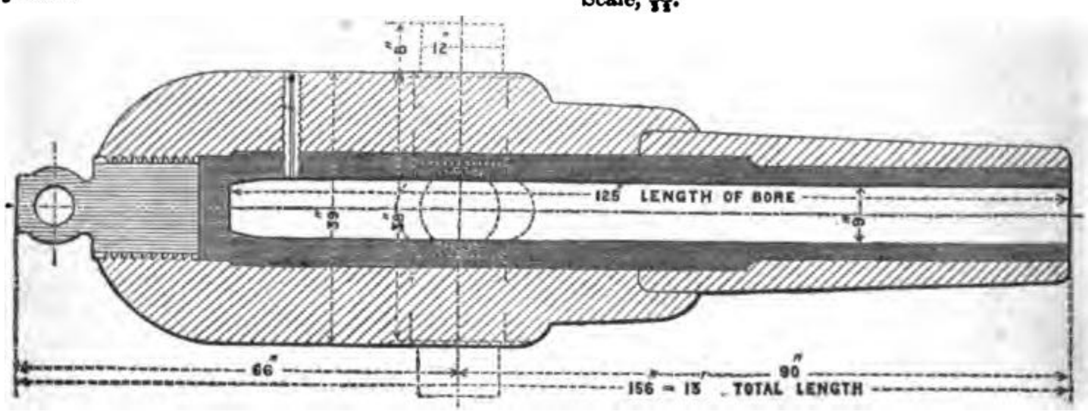


This pattern differs from the Mark I both in external form and construction, being similar to the Mark II in 8-inch, except that the barrels were all made of steel. The length of rifling was reduced to 8 feet 8 inches except in a few of the first, in which it was 8 feet 11·5 inches as in Mark I. Twenty-six of this kind were sent out, and they were stamped with the letter F I on the trunnion until 1868, when the new system of marking commenced.

9-inch, 12 tons Mark III. § 1642.

9-INCH. 12 TONS. MARK III.

Scale, $\frac{1}{32}$.



The Mark III was approved in 1868, and 136 of this pattern were made, a few being stamped F II at first. Experiments with a gun of this kind, together with one which was built up on an improved system, led to the adoption of another method of construction, which is shown in the drawing of Mark IV.

An experimental gun was built up with a coiled breech-piece, and the steel barrel was reduced in thickness, from 3 to 2 inches. The dimensions of the gun were unaltered, except that the breech-piece again became evident in the exterior form of the gun.

* There are no guns in this series with five grooves in the rifling, nor with eight, as may be noticed hereafter.

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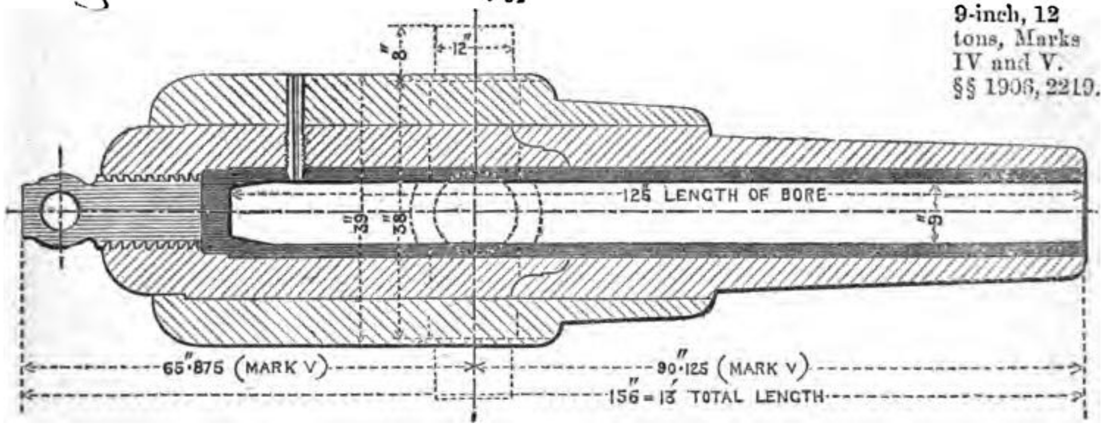
9-INCH. 12 TONS. MARKS IV AND V

Scale, $\frac{1}{32}$.

9-inch, 12 tons, Marks IV and V. §§ 1906, 2219.



This construction was adopted in 1869 as a Mark IV; but the preponderance proved to be rather too great, so a Mark V was designed which only differed from the Mark IV in position of the trunnions; these were placed ·375 of an inch further back.

The rifling consists of six grooves, with a twist increasing from zero to one turn in 45 calibres at the muzzle.

The Mark I has a cylindrical chamber, but in all later patterns the chamber is conical.

The 9-inch, like all heavy guns, are side and centre-sighted. The socket hole for the centre hind-sight ought to be deepened to receive the newer pattern or lengthened sight-bar. This remark applies also to the 10, 11, and 12-inch R.M.L. guns up to 25 tons, and all that have been so prepared should be stamped in front of the socket with the letter D.*

The copper bush for 9-inch and all heavier R.M.L. guns is only partially provided with a screw thread, which extends for 6 inches from the top of the cone; this length, however, has proved quite sufficient to secure the bush in the gun.

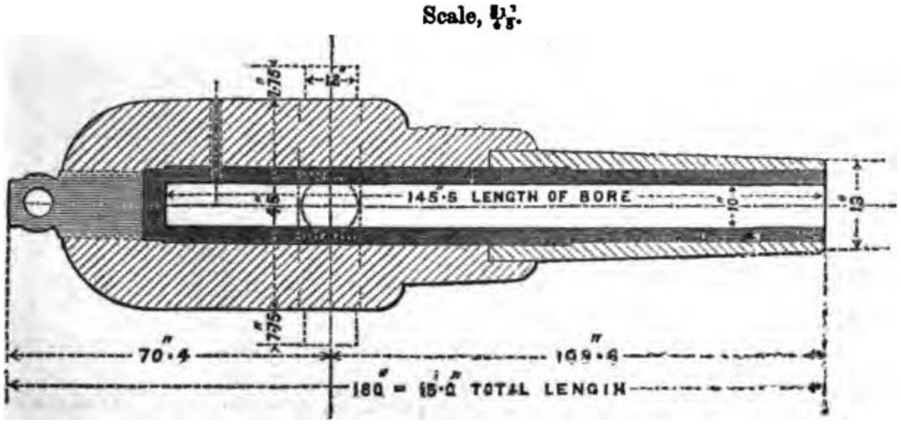
10-*inch R.M.L. Guns.*

There are two Marks of 10-inch. The first was proposed in 1865, owing to the success of the 9-inch, but it was not introduced into the Navy till 1868. They are now used either for L.S. or S.S.

10-INCH. 18 TONS. MARK I.

Scale, $\frac{1}{45}$.

10-inch, 18 tons, Mark I § 1688.



* Appendix, p. 382.

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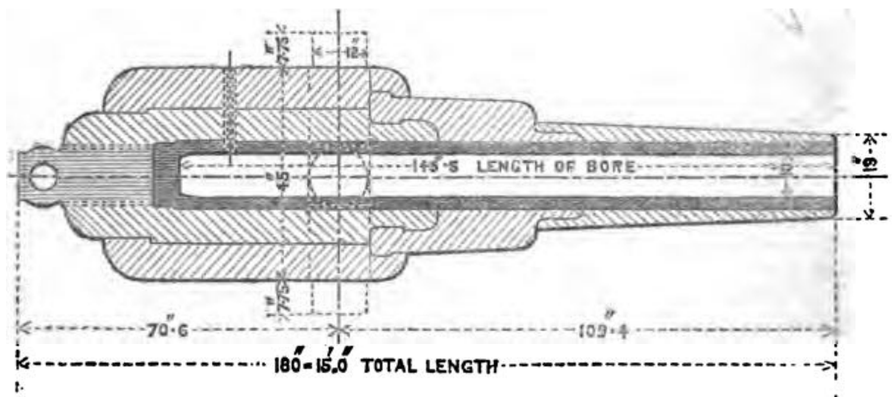
There are only 18 guns of Mark I, which were built up on the "Fraser" construction, so in this respect they correspond with Mark III in the foregoing natures of heavy R.M.L. guns. In the following year this mode of construction was superseded by the R.G.F. system, but when applying the new method of construction to this calibre of gun a slight departure was made from the portions which constituted a 9-inch Mark V; in fact the 10-inch Mark II was the earliest nature which fully embodied the system of manufacture developed in the Royal Gun Factory and now known as the "R.G.F. system."

10-inch, 18 tons, Mark II. § 1905.

10-INCH. 18 TONS. MARK II.

Scale, $\frac{1}{48}$.



This gun consists of six parts, viz.: the barrel, breech-piece, B coil, B tube, jacket, and cascable.

The 10-inch guns are rifled with seven grooves, the twist increasing from 1 turn in 100 to 1 in 40 calibres, the maximum pitch being reached at the muzzle.

The vent is placed on the right side in a forward position, radially situated, but at an inclination of 45° with the vertical plane which passes through the axis of the piece. For S.S. when the guns are mounted in turrets, the left gun in each turret is vented in a similar manner on the left.

10-inch and all heavier guns are bell-mouthed at the muzzle to facilitate loading; the grooves also are splayed for the same purpose by cutting away the metal in the bore for a short distance on the loading side of each groove. The amount of splay may differ even in the same nature of gun; but the half and three-quarter splay will be changed in course of time to the full amount. This point affects the tampeons which ought to fit tightly in the muzzle.

A few of these guns for L.S. which are mounted on small-port carriages have the side-sights placed nearer the centre than the service position: this has been done to obtain a line of sight through the port. The Mark I derricks for 10-inch guns have been found at certain ranges to interfere with this line of sight; the evil, however, has been remedied in the derrick Mark II for these guns.

11-*inch R.M.L. Guns.*

There are two Marks of 11-inch guns corresponding with the two Marks of 10-inch, and notwithstanding the change of calibre their

CHAP. IV.

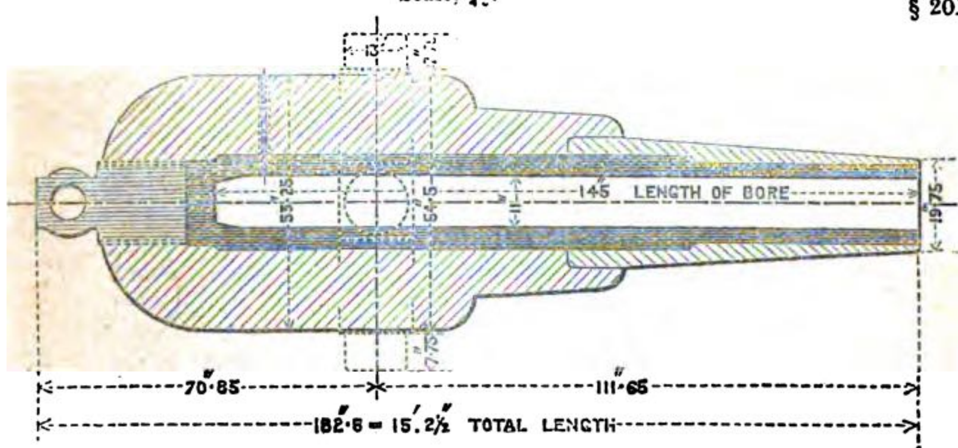
length is as nearly as possible the same, although the weight is increased from 18 to 25 tons. With heavier projectiles the number of grooves was increased; there are nine in this and all the heavier muzzle-loading guns, which have the "Woolwich" system of rifling.

The introduction of this nature was due not so much to the steady progress in size, as to the question of calibre for a gun of this weight: 25-ton guns had already been made, but with a 12-inch calibre; the length had been limited by the Admiralty, and experiments were conducted by the Ordnance Committee to determine the best calibre for power. Ultimately *both* calibres were adopted, and the similarity between 11 and 12-inch guns of 25 tons is apt to lead to confusion, for there is no difference in external appearance or rifling; the only point (and one by no means conspicuous) by which these guns can be known or distinguished is by the diameter of bore.

11-inch, 25 tons, Mark I. § 202.

11-INCH. 25 TONS. MARK I.

Scale, $\frac{1}{4}$.

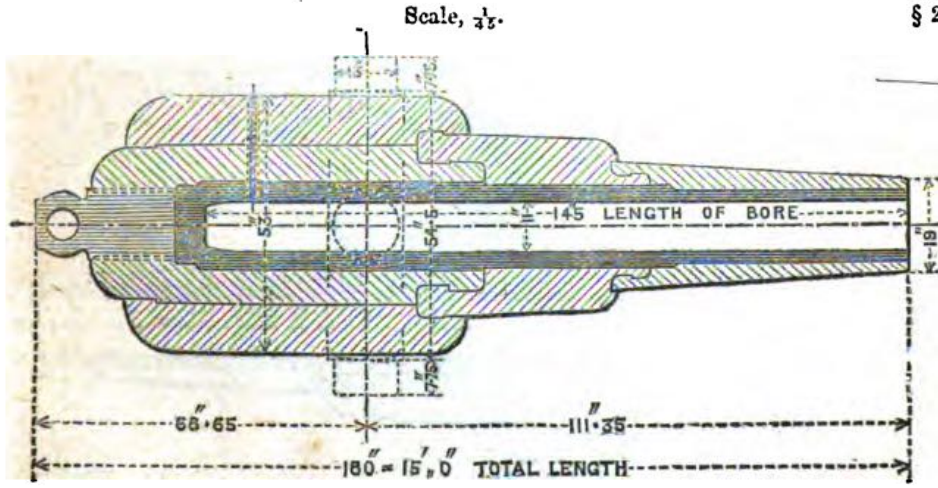


Introduced in the year 1867, the Mark I is of "Fraser" construction, but only seven were made; the manufacture was then suspended for two or three years.

11-inch, 25 tons, Mark II. § 2102.

11-INCH. 25 TONS. MARK II.

Scale, $\frac{1}{45}$.



In 1871 a drawing was sealed for Mark II, and a considerable number of this pattern were made. These were constructed on the

CHAP. IV. R.G.F. system: one gun, however, No. 68, differs from the rest in having a forged breech-piece; this arose from its being originally a 12-inch gun of early construction, which was re-tubed as a 11-inch.

There are nine grooves in the rifling, and the twist increases from 0 to 1 turn in 35 calibres at the muzzle.

The position of the vent for these guns is similar to that described for the 10-inch.

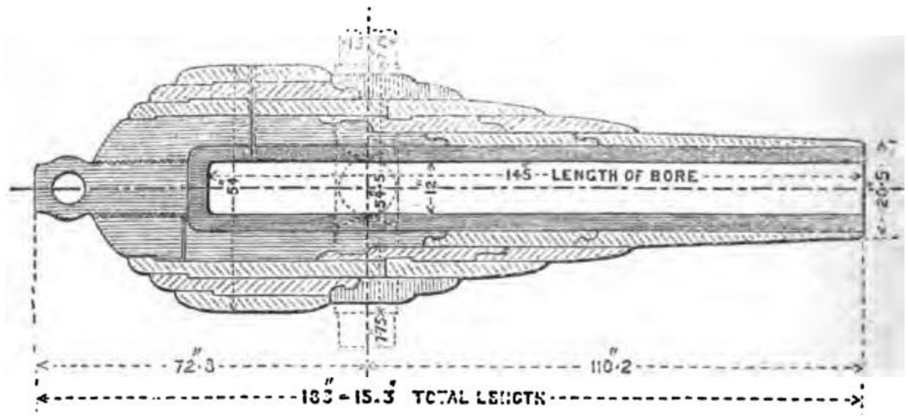
12-*inch R.M.L. Guns*, 25 *tons*.

These are two marks of this nature, which are nominally called by the same weight. In proportion to calibre these are the shortest guns in the service; the bore is only 12 calibres in length. They are chiefly used in the Navy as turret guns, but a few have been mounted for coast defence.

12-inch, 25 tons, Mark I. 2022.

12-INCH. 25 TONS. MARK I.

Scale, $\frac{1}{48}$.

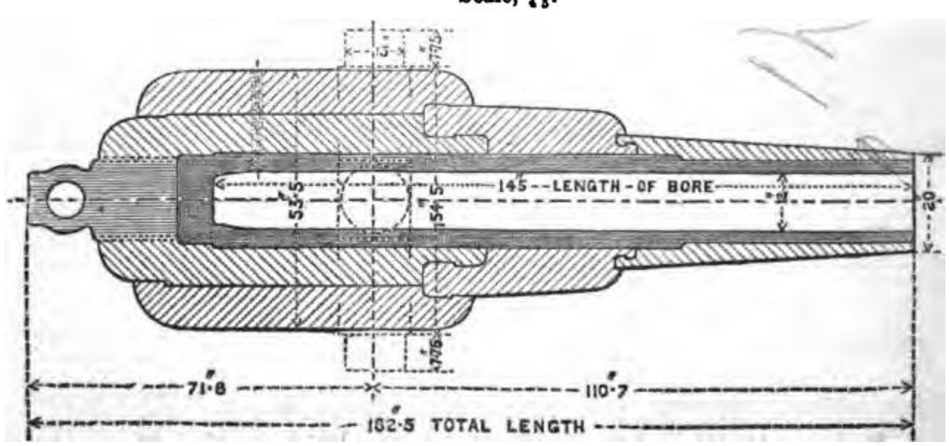


This gun was recommended as early as 1864 to compete with the 13-inch guns of similar weight, but the trials were not carried out until 1866. The 13-inch guns (of which only a few had been made) were afterwards withdrawn from the service; and only six of the

12-inch, 25 tons, Mark II. § 2022.

12-INCH. 25 TONS. MARK II.

Scale, $\frac{1}{48}$.



12-inch Mark I remain serviceable now. The actual weight of these guns is 23⅜ tons, but they are classed with the 12-inch of 25 tons, to avoid forming a separate nature. They are built on the "Original" system.

Under this designation are comprised all the 12-inch R.M.L. guns weighing actually 25 tons; 4 were built on the "Original" system, 8 on the modified, and 2 on the Fraser construction; the remainder were made on the R.G.F. plan, which alone is shown in the drawing.

In 1878 four guns of this class were manufactured by the E.O.C. for sea-service: these differ from the sealed pattern Mark II in dimensions but not in the system of construction (see § 3659). They were provided for the armament of H.M.S. "Belleisle," and are known by their Elswick numbers, 3363, 3372, 3373, and 2376. § 3659.

The sights and fittings are alike for all 12-inch of 25 tons except that a difference exists in the form of the elevating plate on the E.O.C. guns arising from its position to suit the special carriages on which they are mounted. Metal scales also for S.S. instead of wood scales are issued with these E.O.C. guns, which are fixed permanently to the rear transom of the carriage, and work on a joint which allows of their being dropped into a clip when not in use. § 3659.

The twist of the rifling increases from 1 turn in 100 cals. to 1 turn in 50 at the muzzle.

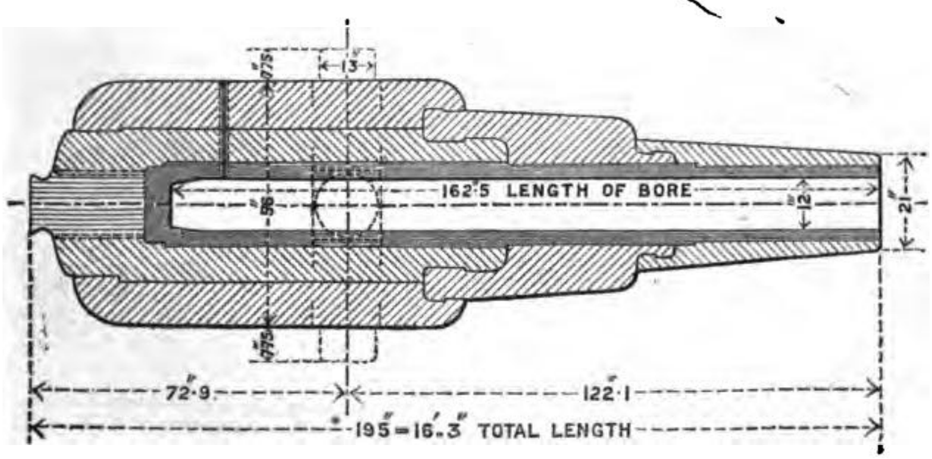
12-*inch R.M.L. Guns*, 35 *tons*.

There is only one Mark of this nature. The first gun was completed in 1871 as a 700-pr. of 11·6 inches calibre; but after a few firing trials it was bored out to 12 inches, and with this calibre it was finally adopted for service. Only fifteen have been made: they are chiefly used as turret guns for S.S., but two are mounted in Ireland.

12-INCH. 35 TONS. MARK I.

Scale, $\frac{1}{80}$.

12-inch, 35 tons, Mark I. § 2440.



These guns are built on the R.G.F. system, and differ from the 12-inch of 25 tons mainly in the length of the bore, which was increased to 13½ calibres; they are also stronger in the breech for

CHAP. IV. the purpose of firing a much heavier battering charge. The projectiles (as well as the charges) are heavier and also of different pattern, so the ammunition is not interchangeable with that supplied for the guns of equal calibre weighing 25 tons.

The cascable was reduced in these guns to a plain button to economise space in a turret.

The grooves, nine in number, have a twist increasing from 0 at the breech to 1 turn in 35 calibres at the muzzle.

Most of these guns, being intended for turrets, were never prepared for ordinary sights; for L.S., however, they are provided with three sets of service pattern in which the centre-sight is exactly the same as those used at the side. When mounted in pairs the vents are placed on the outer sides, and their elevating plates on the inner.*

12·5-*inch R.M.L. Guns.*

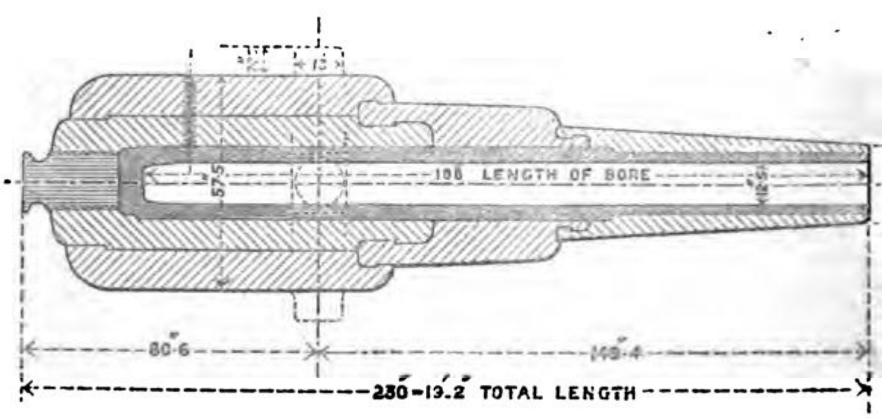
Although the dimensions of the foregoing guns were suitable for the limited space in a turret, their power did not prove to be commensurate with weight; they were too short for a 12-inch calibre, so in 1873 a longer gun was provisionally approved which was 3 feet longer in the bore and weighed about 38 tons; two only however were issued with this calibre,† and both these have since been destroyed.

In 1874, after a series of experiments at Shoeburyness, it was determined that the calibre should be 12·5 inches.

12·5-inch, 38 tons, Mark I.

12·5-INCH. 38 TONS. MARK I.

Scale, $\frac{1}{80}$.



In construction this gun resembles the 35-ton gun just described: it differs only in dimensions and weight. The cascable also is solid, but not quite so small in the neck.

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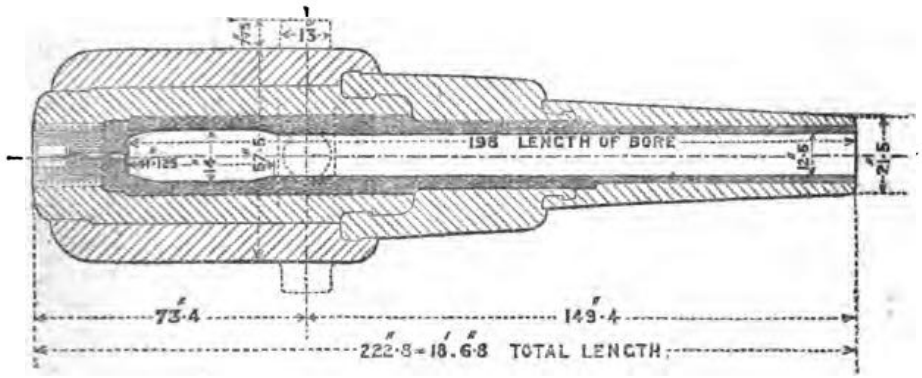
* This remark applies to all R.M.L. guns when mounted in turrets.

† Nos. 2 and 3 of 12-inch calibre were placed on board H.M.S. "Thunderer," which had 35-ton guns in the fore turret, in order that the ammunition might be exactly the same for all her heavy guns. These were both burst by double-loading, one in the Black Sea on board ship, and the other in carrying out experiments at the Proof Butts in 1879–80.

12·5-inch, 38 tons, Mark II.

12·5-INCH. 38 TONS. MARK II.

Scale, $\frac{1}{60}$.



The Mark II differs from the Mark I in having an enlarged powder chamber and in being axially vented. In construction, dimensions, and outline, the guns are alike; in fact, the Mark II was merely a conversion of guns previously made, for in 1880 it was decided to adopt the enlarged chamber in some of the 12·5-inch guns in order to fire heavier charges. The alteration consisted in boring out the chamber to a diameter of 14 inches, with a total length including the cone at each end of 41·125 inches. The capacity is 6,000 cubic inches. In cutting away the metal to this extent several inches of the rifling were necessarily removed, and there is no stop in the bore to prevent a projectile from being rammed into the chamber. Such an accident at drill would lead to great difficulty of extraction, and at practice to considerable danger. To prevent over-ramming the charge when P^2 powder was used, the cartridges were made up to the proper length with stout sticks in the middle; but now prismatic powder should be fired in these guns, and the built-up cartridges are sufficiently rigid: this point, however, should not be forgotten, for if the charge were at any time reduced, or the powder necessarily changed, the danger would again be apparent.

In selecting guns for alteration to the Mark II, only those which had an extra thickness of steel have been taken. The boring out of 1·5 inches of metal leaves the steel barrel of just the same thickness as in the Mark I, but by reduction of pressure in the chamber the strain is diminished.

Special guns for H.M.S. "Ajax."

A few 12·5-inch Mark II have been made for S.S. with trunnions of different dimensions to those of the service pattern. For H.M.S. "Ajax" and "Agamemnon" the trunnions have a length of 13 inches instead of 7·75; and in the "Neptune" class both the length and diameter are increased, viz., to 9·1 and 14 inches respectively. The departure in the latter case from a service diameter will prevent these guns from ever being mounted on an ordinary carriage.

Two elevating bands are shrunk on to all the "Ajax" and "Agamemnon" guns, holding a bracket underneath the breech which gives the means of attachment (through a bolt) to the sliding bracket which works on the elevating bar of the hydraulic carriage.

Axial vent.

The projecting part of the cascable is entirely removed and a recess cut into the breech to receive the axial vent. This consists of a steel bolt containing the vent channel; the end within the gun is mushroom-shaped, and is furnished with a copper washer to make a gas-tight

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junction between the vent-bush and the bottom of the bore; the other end in the recess at the breech is fitted with a cross-handled removable head, which is prepared to receive a vent-sealing tube, either of electric or frictional pattern. The latest form of tube-holder is supplied with an automatic extractor.

Cradle.

Cradles are issued with all R.M.L. guns using this kind of axial vent, for removal and exchange of the bush (p. 162).

A bronze cover (at first called "Frame," now "Socket") is attached to the breech by fixing screws to close the recess formed to take the slinging cascable, and to support the end of the vent, which passes through it (p. 172).

Shutter.

A door or shutter (p. 172) also is attached to the outside of the breech, to guard against accident which might arise from defective tubes, and for security in case the tube-holder should not be quite properly put on; the shutter itself contains an automatic arrangement to render this impossible when closed.

Slinging cascable.

A removable cascable similar in shape to the trunnion stud (p. 170) is issued to each fort or ship in which guns of this pattern are mounted, for use in slinging the piece; the vent bush, shutter, &c., must be taken off before this block can be screwed into the breech.

Trunnion studs.

Trunnion studs are provided for a similar purpose, which may be used with either Mark of these guns; and washers are supplied to be placed between the stud and the trunnion to prevent the sling from slipping off on to the latter.

Sights.

The tangent sights (which are at present graduated only in degrees), and the trunnion and centre fore-sights, are available for either Mark I or Mark II. There is no difference between the centre hind-sight and the tangent sight at the side. These hind-sights have the shallow L.S. notch, and are furnished with a slow-motion nut for adjustment to one minute of elevation.

16-*inch R.M.L. Guns.*

80-ton experimental gun.

In 1873 it was proposed to construct a more powerful gun than any of the ordnance made up to that time, and in the following year the manufacture of an 80-ton gun was commenced. This was completed in 1875 with a calibre of 14·5 inches. After some experiments at the Proof Butts, which were very satisfactory, it was bored up to 15 inches, and again after the firing trials at Shoeburyness it was bored up once more, and this time to its final calibre. The experimental gun was rifled on the Woolwich system, but the rifling was afterwards changed in the manufacture of service guns to the M.M. polygroove type.

The guns are built up on the R.G.F. system of the same parts as the 38-ton R.M.L. guns except that owing to increase of length the B coil is put on in two parts.

The powder chamber is enlarged to a diameter of 18 inches, and it has a total length to the base of the projectile of 59·6: giving a capacity of 14,600 cubic inches.

16-INCH. 80 TONS. MARK I.

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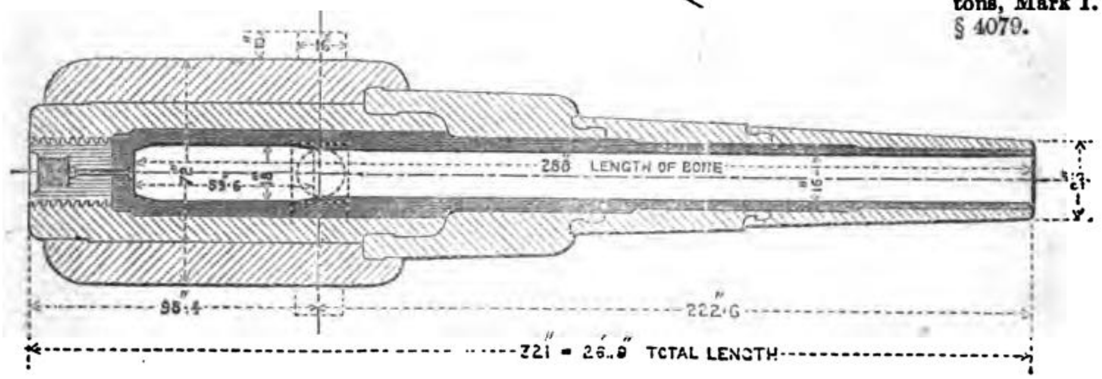
Scale, $\frac{1}{150}$.

16-inch, 80 tons, Mark I. § 4079.



The rifling consists of 33 grooves, of M.M. section, with a twist which increases from 0 to 1 turn in 50 calibres. The nature of this twist is represented by a semi-cubical parabola, $x^{\frac{3}{2}} = py$, which will be found in no other gun; this kind of parabola has the property of developing the twist more gradually than the conic or ordinary curve, and therefore is better suited for a projectile of very great weight.

The grooves end abruptly a short distance in front of the chamber, thus forming a stop for the projections on the gas-check at the base of the shell, so that a projectile cannot enter the chamber, and the density of the charge is regulated to a constant amount.

The gun is fitted axially with a steel removable vent-bush, which is of the same description as that supplied for the 12·5-inch gun Mark II, but it differs in length and in a few little matters of detail The arrangements of vent-head, cover, and shutters are just the same; but a different cradle is necessary, with suitable block and additional length in the handle.

All 80-ton guns are mounted in turrets, both for L.S. and S.S., and the turrets are fitted with sights. For land service the guns are also prepared for chase sights.

Sighting arrangement of Dover turret.

The turret at Dover has two sighting holes, one to each gun, and a set of compound sights is fitted to each. The sights are connected by cross shafts, clutches, and spur gearing, with two dials, the pointers of which record the elevation at which the sights are adjusted. The provisions thus made permit of either sight working the pointers of both dials at once, or by disconnection actuating the particular dial associated with the gun next to it, when independent firing is required.

In laying the sight on an object, the inner sight bar, which is inclined at the deflectional angle, is elevated to the required range with rack, pinion, and worm-gearing, by means of a small hand-wheel, the elevation in yards being indicated through a window, reading from the graduated circumference of a wheel worked from a spindle, the sight being retained in its elevated position by a worm and wheel. The sight with its socket and attachment is then lowered to the same level as the object, bodily, by rack and pinion, actuated by a hand-wheel, the whole sliding within a permanent socket which passes through the turret roof.

In thus elevating or depressing the sight, the same amount of motion is automatically recorded by a pointer on the dial plate fixed to the roof immediately over the elevating wheel of the gun. The spindle to which this pointer is fixed revolves within a sleeve, to which is

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attached a second pointer in connection with the gun. When the sight and gun are at zero these two pointers are in line with each other, and whilst the sight is being manipulated, the man at the elevating wheel elevates or depresses the gun, so as to keep one pointer over the other.

A mechanical arrangement, consisting of a splayed bracket attached to the 1 B coil of the gun, and which engages the lever of a rocking shaft, communicates motion to the pointer, thereby recording the elevation of the gun. The duty of the number at the elevating wheel is to keep the two pointers continually together. When the gun is fired, the splayed bracket retires from engagement with the mechanical arrangement referred to, and when the gun is again run out the communication is renewed.

A deflection of 3° right and left may be given on the leaf, and the sight head can be removed from the bar when not in use, the latter being then housed and covered by a watertight cap, screwed on the outer socket.

The fore-sight is of the acorn type fixed in a bar, which slides within a socket passing through the turret roof; it is elevated from the interior of the turret by means of a cross handle, and is held in position by a bayonet-joint arrangement; when housed it is covered with a spring watertight cap.

Index plates and readers are to be fitted to each gun and carriage, to serve as a permanent check to the above sighting arrangements.

Elevating bands.

For S.S. two elevating bands are shrunk on the breech, holding a wrought-iron bracket to the gun. This bracket gives the means of attachment, through a bolt, to the sliding bracket which works on the elevating bar of the carriage.

Guide patches are also attached for S.S. to each side of the gun to steady the piece in running out.

For L.S. an elevating bracket is screwed on the underside of the breech, and it is attached to the elevating gear by studs.

Cascable and trunnion studs are furnished as spare stores for each turret or ship; preserving studs should be kept in the trunnions that the screw threads may not get injured or clogged. The trunnion studs are provided with washers or collars, with can be unscrewed for the reception of lifting shackles.

17·72-*inch R.M.L. Guns.*

In 1878 four 100-ton guns were purchased from the Elswick Ordnance Company; two are mounted at Malta and two at Gibraltar, on special carriages, the loading, elevating, and traversing work being carried out by hydraulic machinery.

The construction of this gun is very different from that on which the 80-ton guns were manufactured at Woolwich. The A tube is made up of two lengths, united by a key ring placed over the joint to link the two parts together, with a ring of copper let in to prevent escape of gas through the joint.

There are eight wrought-iron coils in the first layer of metal which completely covers the barrel; four coils and a forged trunnion ring in the second layer; and four coils again in the third over the breech end, one of which is in front of the trunnions. The trunnion ring and all the coils were separately shrunk on, a system which reduces the longitudinal strength of the gun almost to the end-strength of the barrel; but the surface of some of the coils was serrated to give an additional grip in the shrinking. This, however, did not prevent longitudinal failure in a similar gun which was purchased by the

government of Italy. The service charge in this country has therefore been very much reduced; it is now the same as for an 80-ton gun, with which it is made interchangeable.

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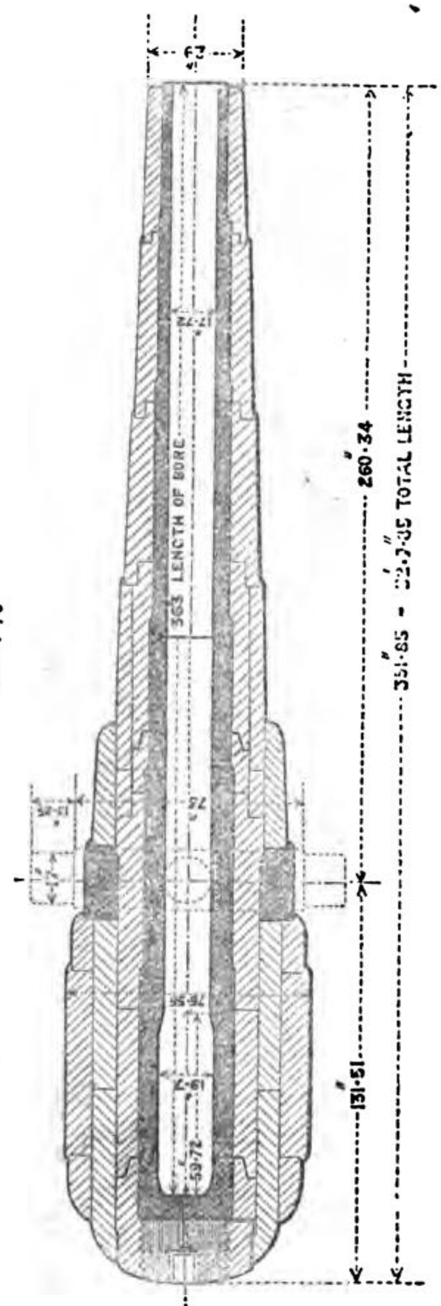
17·72-inch, 100 tons, Mark I. § 4372.

17·72-INCH. 100 TONS. MARK I.

Scale, $\frac{1}{70}$.



The guns are rifled on an Elswick polygroove system with 28 grooves, the spiral increasing from a twist of 1 turn in 150 calibres to 1 in 50 at a distance of 2·88 inches from the muzzle, the remainder being uniform at 1 in 50.

The chamber at first was cylindrical with a diameter of 19·7 inches, terminating at each end with a frustrum of a cone. The angles have since been rounded off and the front cone has been curved into the bore.

The gas-check on the projectile is stopped by the termination of the

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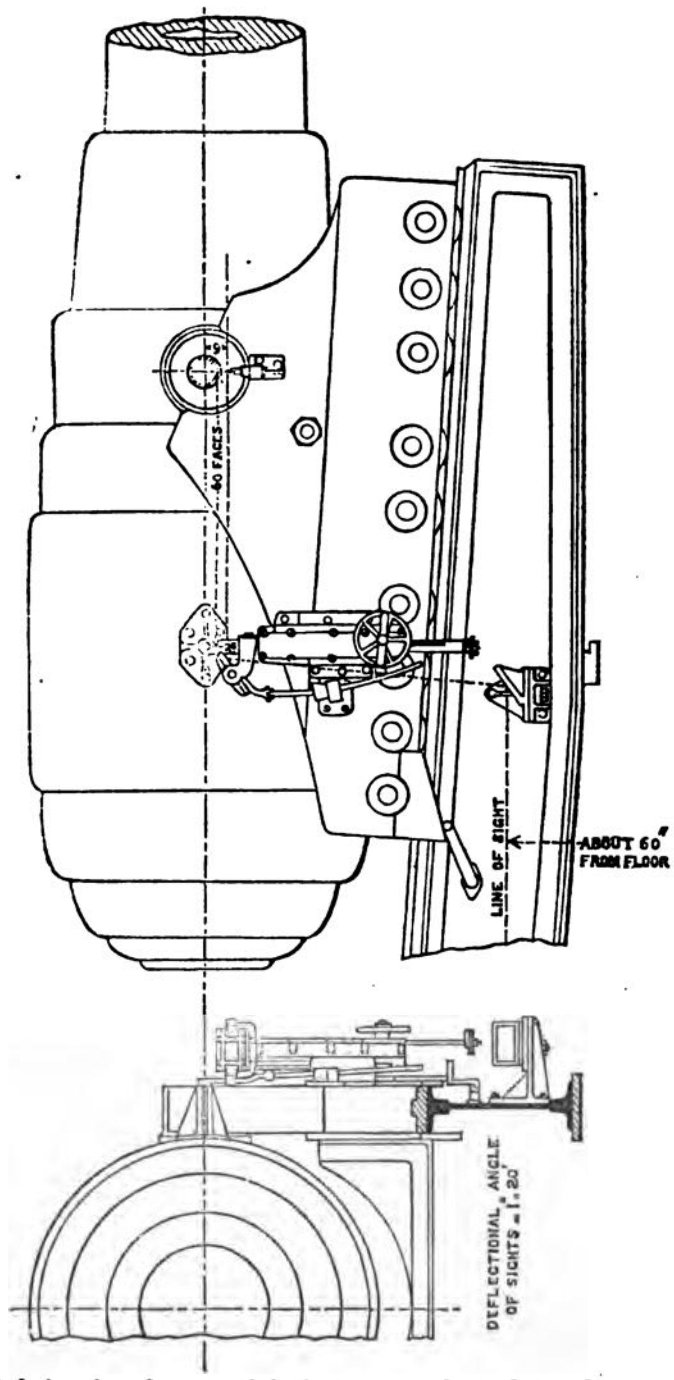
grooves, at a distance of 59·72 inches from the end of the bore. This gives a capacity to the chamber of 17,049 cubic inches.

These guns have been vented in R.G.F. since purchase with axial removable bushes exactly in the same manner as the 80-ton guns, and a safety shutter is added to guard against accidents.

GENERAL ARRANGEMENT OF SIGHTING.

(Scale, $\frac{1}{48}$.)



The sighting is of a special character, adapted to the mounting of these guns *en barbette*. Two sets are provided, one on each side.

The fore-sight is a steel acorn drop sight, affixed to a bracket on the carriage immediately under the centre of the trunnion.

The hind-sight has a crutch carrying the upper mirror, which is in

connection with a copying bar working in a guide attached to the carriage, and so arranged that, however the angle of elevation or depression may vary, the necessary compensation is made on the mirror to insure the line of sight being always reflected to one spot in the lower mirror.

The hind-sight bar moves in a socket working within a guide bracket secured to the carriage by fixing screws, and is traversed by the gun, to which it is attached by a connecting rod. The angle of deflection is 1° 20′.

Elevation is given to the sight bar by means of a hand wheel turning a pinion, which gears into a rack on the front edge of the bar.

Deflection is given by a small plate wheel at the bottom of the hind-sight bar, graduated to $1\frac{1}{2}$ degrees right and left.

The bracket for the lower mirror is attached to the platform by fixing screws. The lower mirror is pivoted and provided with a clamping nut, so that it may be fixed at any angle to suit convenience in laying.

The person laying the gun stands facing the object, and having adjusted the hind-sight to the required elevation (or depression) and deflection, elevates, or depresses, and traverses the gun till the object and the top of acorn of fore-sight and notch of hind-sight are reflected together in the lower mirror.

Trunnion studs and dismounting blocks are supplied to these as well as to the 38- and 80-ton guns, and in addition a cast-iron counterbalance to counteract preponderance (p. 162).

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TABLE XXI.

Dimensions, Rifling, &c., of R.M.L. Guns.

Nature.	Weight.	Calibre.	Mark.	Length. Nominal.* ft.	Length. Nominal.* ins.	Length. Of Bore. Inches.	Length. Of Bore. Calibre.	Length. Of Rifling.	Chamber. Length.	Chamber. Diameter.	Chamber. Capacity.	Rifling. System.	Rifling. Twist in Calibres.	Grooves. Number.	Grooves. Depth.	Grooves. Width.	Preponderance.	Remarks.
		inches.		ft.	ins.			Inches.	Inches.	Inches.	c. i.							
7-pr. steel	150 lb.	3	I, II, & III	2	2½	24	8	22	—	—	—	French	U. 1 in 20	3	·1	·6	I & II 5 lb. III 3 lb.	
7-pr. steel	200 lb.	3	IV	3	2·9	36	12	34	—	—	—	"	"	3	·1	·6	5 lb.	
7-pr. bronze	209 lb.	3	II	3	0	32·15	11	29·15	—	—	—	French	U. 1 in 20	3	·1	·6	45 lb.	
7-pr. bronze	224 lb.	3	III	3	0	34	11	32	—	—	—	"	"	3	·1	·6	5 lb.	
2·5 inch	400 lb.	2·5	I	5	10·45	66·5	26	54·73	11·07	2·56	54	Maitland	I. 1 in 80 to 1 in 30	8	·05	·5	—	Jointed gun.
9-pr. ...	6 cwt.	3	I	4	10	53	17·6	49·3	—	—	—	Modified French	U. 1 in 30	3	·11	·8	3 lb.	S.S. only.
		3	II	5	11	66	22	62·3	—	—	—	"	"	3	·11	·8	10 lb.	L.S. only.
		3	III	5	11	66	22	62·3	—	—	—	"	"	3	·11	·8	—	S.S. only.
	8 cwt.	3	I	5	8½	63·5	21	59·8	—	—	—	"	"	3	·11	·8	7 lb.	L.S. only.
		3	II	5	8½	63·5	21	59·8	—	—	—	"	"	3	·11	·8	7 lb.	S.S. only.
13-pr.	8 cwt.	3	I	7	3·96	84	28	67	14·33	3·15	110·38	Maitland	I. From 0 to 1 in 30	10	·05	·5	—	
16-pr.	12 cwt.	3·6	I	6	2·45	68·4	19	58·04	—	—	—	Modified French	U. 1 in 30	3	·11	·8	7·5 lb.	
25-pr.	18 cwt.	4	I	7	10·5	88	22	78	—	—	—	Woolwich	U. 1 in 35	3	·1	·8	14 lb.	
40-pr. ...	34 cwt.	4·75	I	8	0	85·5	18	72·5	—	—	—	"	"	3	·1	·8	28 lb.	
	35 cwt.	4·75	II	9	6·75	104·5	22	90·5	—	—	—	"	"	3	·1	·8	25 lb.	
64-pr. (converted)	58 cwt.	6·3	I	9	6	108·45	17·2	101·45	—	—	—	Plain	U. 1 in 40	3	·115	·6	—	
	71 cwt.	6·3	I	9	0	103·27	16·4	96·27	—	—	—	"	"	3	·115	·6	6·375 lb.	*All 64-pr. guns having steel tubes, and all others which may have been re-tubed with coiled iron, have the plain groove.
90-pr. ditto	5 tons	6·3	I	10	0	113·25	18	106·25	—	—	—	Woolwich	"	3	·145	1·3	9·75 lb.	
64-pr.	64 cwt.	6·3	I	9	2½	98	15·5	90·5	—	—	—	Shunt or Plain*	"	3	·08 and ·11	·4 and ·6	7 lb.	
			II	9	5	98	15·5	90·5	—	—	—	"	"	3			3 lb.	
			III	9	3½	97·5	15·5	90·5	—	—	—	Plain	"	3	·11	·6	3·75 lb.	
6·6-inch	0 cwt.	6·6	I	9	10	97·5	15	76·5	21	6·8	707	Maitland	I. From 1 in 100 to 1 in 35	20	·05	·7	13 lb.	

TABLE XXI.

Dimensions, Rifling, &c., of R.M.L. Guns—*continued.*

Nature.	Weight.	Calibre.	Mark.	Length. Nominal.* ft.	Length. Nominal.* ins.	Length. Of Bore. Inches.	Length. Of Bore. Calibre.	Length. Of Rifling.	Chamber. Length.	Chamber. Diameter.	Chamber. Capacity.	Rifling. System.	Rifling. Twist in Calibres.	Grooves. Number.	Grooves. Depth.	Grooves. Width.	Preponderance.	Remarks.
		inches.		ft.	ins.			inches.	inches.	inches.	c. i.							
7-inch ...	90 cwt.	—	I	10	4½	111	16	95·5	—	—	—	Woolwich	U. 1 in 35	3	·18	1·5	5 cwt.	
	6½ tons	7	I	10	5½	111	16	97·5	—	—	—	"	"	3	·18	1·5	5·5 cwt.	
			II & III	10	6	111	16	95·5	—	—	—	"	"	3	·18	1·5	3 cwt.	
	7 tons	7	I	11	10·8	126	18	112·5	—	—	—	"	"	3	·18	1·5	4·5 cwt.	L.S. only.
			II, III, IV,	11	9·5	126	18	110·5	—	—	—	"	"	3	·18	1·5	3 cwt.	
8-inch	9 tons	8	I	11	4½	118	14·7	102	—	—	—	"	I. From 0 to 1 in 40	4	·18	1·5	Nil.	S.S. only.
			II & III	11	4½	118	14·7	99·5	—	—	—	"	"	4	·18	1·5	4 cwt.	
9-inch	12 tons	9	I, II, III,	12	3	125	14	107·5	—	—	—	"	I. From 0 to 1 in 45	6	·18	1·5	Nil.	* Those made before 1 Jan., 1868, have length of rifling the same as Mark I.
			IV & V	12	3	125	14	104½*	—	—	—	"	"	6	·18	1·5	5 cwt.	
10-inch	18 tons	10	I	14	2	145·5	14·5	118	—	—	—	"	I. From 1 in 100 to 1 in 40	7	·2	1·5	Not to exceed 3 cwt.	
			II	14	2¾	145·5	14·5	118	—	—	—	"	"	7	·2	1·5		
11-inch	25 tons	11	I	14	3	145	13	119	—	—	—	"	I. From 0 to 1 in 35	9	·2	1·5		L.S. only.
			II	14	2	145	13	119	—	—	—	"	"	9	·2	1·5		
12-inch	25 tons	12	I	14	3½	145	12	127	—	—	—	"	I. From 1 in 100 to 1 in 35	9	·2	1·5		
12-inch	35 tons	12	I & II	15	11¾	162·5	13·5	135	—	—	—	"	I. From 0 to 1 in 35	9	·2	1·5		
12·5-inch	38 tons	12·5	I	18	9½	198	16	170·5	—	—	—	"	"	9	·2	1·5		
			II	18	9½	198	16	156·725	41·125	14	6000	"	I. From 1 in 438 to 1 in 35	9	·2	1·5		
16-inch	80 tons	16	I	26	9	288	18	228·4	59·6	18	14600	Maitland	I. From 0 to 1 in 50	33	·1	1·0		
17·72-inch... ...	100 tons	17·72	I	32	10	363	20	302·88	59·72	19·7	17049	Elswick	I. From 1 in 150 to 1 in 50	28	·125	1·1	80 cwt.	L.S. only.

* Measured from face of muzzle to smallest diameter of cascable, excepting those converted from S.B., then to back of base ring only.

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TABLE XXII.

TABLE of BALLISTICS for R.M.L. GUNS.

Guns.	Mark.	With: Charge. Weight.	With: Charge. Description of Powder.	With: Projectile, Weight.	Muzzle Velocity.	Muzzle Energy.	Penetration of Wrought-iron Armour-plate. At 1,000 yards.	Penetration of Wrought-iron Armour-plate. At 2,000 yards.
		lb.		lb.	f.s.	ft. tons.	ins.	ins.
17·72-in., 100 tons	I	450	Prismatic	2,000	1,548	33,233	22·8	21·0
16-in. 80 ,,	I	450	,,	1,700	1,604	30,329	23·3	21·7
12·5-in. 38 ,,	I	160	P²	818	1,445	11,842	16·1	14·8
12·5-in. 38 ,,	II	210	Prismatic	818	1,546	13,554	17·1	15·8
12-in. 35 ,,	I	140 110	P² P	714 714	1,390 1,300	9,125 8,367	15·3 14·9	14·1 13·5
12-in. 25 ,,	II	85	,,	614	1,300	7,195	13·3	12·0
11-in. 25 ,,	II	85	,,	547	1,315	6,559	13·4	12·0
10-in. 18 ,,	II	70	,,	410	1,364	5,288	12·2	10·9
9-in. 12 ,,	V	50	,,	258	1,420	3,607	10·2	8·7
8-in. 9 ,,	III	35	,,	180	1,413	2,492	8·3	7·0
7-in. 7 ,,	IV	30	,,	115	1,540	1,891	7·2	5·9
7-in. 6½ ,,	III	30	,,	115	1,525	1,854	7·2	5·9
7-in. 90 cwt.	I	22	,,	115	1,361	1,477		
6·6-in. 70 ,,	I	25	,,	100	1,416	1,390		
64-pr. 64 ,,	III	8	R.L.G.³	65	1,260	715		
80-pr. {converted, 5 tons}	I	20	,,	80	1,558	1,346		
64-pr. 64 cwt.	I & II	8	,,	64·5	1,170	612		
64-pr. {converted, 71 cwt.}	I	8	,,	65	1,125	570		
64-pr. {converted, 58 cwt.}	I	8	,,	65	1,225	570		
40-pr. 34 ,,	I	7	,,	38	1,340	473		
40-pr. 35 ,,	II	7	,,	40	1,425	563		
25-pr. 18 ,,	I	4	,,	25	1,340	311		
16-pr. 12 ,,	I	3·0	,,	16·1	1,355	203		
3-pr. 8 ,,	I	3·125	,,	13·25	1,560	221		
9-pr. 8 ,,	I & II	1·75	,,	8·92	1,330	109		
9-pr. 6 ,,	I	1·5	,,	8·92	1,234	94		
9-pr. 6 ,,	II & III	1·75	,,	8·92	1,390	121		
2·5" {jointed, 400 lb.}	I	1·5	R.L.G.³	7·375	1,440	100		
7-pr. bronze 200 lb.	II	...	R.L.G.	...	914	40		
7-pr. steel 150 ,,	III	0·375	R.F.G.	7·3	673	23		
7-pr. ,, 200 ,,	IV	0·75	,,	7·3	950	46		

PART II. R

CHAPTER V.

R.M.L. CONVERTED GUNS.

History of the introduction of R.M.L. converted guns.—Palliser method of conversion.—Natures of S.B. pieces selected.—Present nomenclature.—Preparation of the cast-iron gun.—Manufacture of the wrought-iron barrel.—The gas channel.—Insertion of the tube.—Completion of the piece as a rifled gun.—Rifling, venting, examination, and proof.—Line of metal.—Sight sockets.—Details concerning the 64-pr. 58-cwt.—The rifle groove.—Sighting.—Clearance angle.—Correction for drift.—Details for the 64-pr. 71-cwt.—The 80-pr. gun.—Difference in rifling for the 80 and 64-prs.—Correctional angle for sighting.—General remarks.—Fittings and stores.

History of the introduction of converted guns.

WHEN rifled artillery first came into general use there existed a very large store of S.B. cast-iron pieces, and for the sake of economy an attempt was made to convert some of these into rifled guns. The material, however, was weak, and it became necessary first to devise some means of strengthening them. Many suggestions were put forward and tried, and the experiments extended over a period of seven or eight years; at last the plan proposed by the late Sir William Palliser was definitely adopted in 1863.

Palliser method of conversion.

This method may be briefly defined as a system of lining a cast-iron gun (slightly bored out for the purpose) with a barrel of coiled iron, mechanically fitted into its case, and expanded into contact by firing a few heavy rounds.

Guns converted on this principle have given very satisfactory results, and a large number have been issued to service, but they have never been considered powerful guns compared with new pieces built up on the Woolwich system of construction; for shell practice, however, within moderate range these guns are effective and useful.

S.B. guns selected for conversion.

Many natures of cast-iron guns were at one time proposed for conversion, but only three were eventually selected; these are mentioned below, with their designation after conversion :—

58 cwt

32-pr.	of 58 cwt.	converted into a	64-pr.	rifled gun of	58 cwt.	? Calibre 5.0
8-inch	of 65	„	64-pr.	„	71 „	
68-pr.	of 95	„	80-pr.	„	5 tons.	6.29

Mode of conversion.

The mode of conversion is the some in each case; the 8-inch gun will be taken as an example.

The cast-iron gun is bored out to a diameter of 10·5 inches;* this is gauged, and the variation of measurement at the breech and the muzzle

* Some 68-pr. guns were bored out to 12 inches, the metal being sufficiently thick in this piece to receive a wrought-iron barrel of larger diameter than that suitable for 8-inch or 32-pr. guns.

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must not exceed 0·1 inch, the taper (if any) being of course in the direction of the breech.

The A tube. The barrel or A tube is prepared by uniting five coils of wrought iron end for end with a spigot and faucet joint, the welding being effected in a uniting furnace by screwing up the lengths forcibly together, and hammering down the bulged portion afterwards. The coil at the breech end is made of smaller diameter than the rest of the tube, in order to receive a second layer or B tube,* which is introduced for the sake of initial compression (as far as this principle can be applied) at the most important part of the gun.

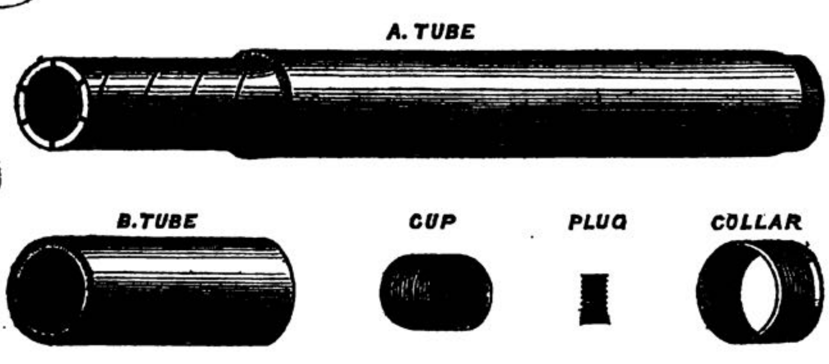
Wrought-iron cup. The barrel is closed at the breech end with a wrought-iron cup, which is stamped into shape under a hammer, turned, threaded and screwed in to its place.

Water test. The tube in this state is proved with a water pressure of 120 lb. on the square inch to ascertain that the cup fits correctly. The breech end is then turned down over a length of 32 inches to receive the B tube, and a spiral gas channel is cut round the exterior of this portion com-

Gas channel. municating with a star groove at the end; a hole is afterwards bored through the cast-iron case to meet the circular part of the latter. This gas escape channel in the first 212 guns converted at Elswick will be found underneath the cascable, but in all others it is situated on the right hand top side of the breech.

B tube. The B tube consists of two coils united together which are bored, turned, finished and gauged. The external diameter of the A tube is then completed to give a shrinkage of $\frac{d}{2666}$. Besides the advantage of initial compression (which, however, cannot be very great after expansion of the barrel in proof) this construction provides a gas channel particularly suitable for a coiled iron barrel to indicate any opening or failure in the inner metal. The shrinkage of the B tube also helps to secure the cup in the end of the barrel.

Putting the gun together. The whole tube is then turned to the dimensions required for the cast-iron case; it is put into the gun with the closest mechanical fit, and the difference of measurements is not allowed to exceed ·007 inch at the breech, or ·015 at the muzzle. The bore is then broached to a diameter of 6·29″.



Fitting the barrel in case. When putting the two main parts of the gun together the case is placed at a convenient angle for the barrel to slide down into position, and great care is taken that the breech end should bear evenly against the cast-iron case. The outer edge also at the end of the tube is

* This B tube must not be confounded with the portion known by the same name in built-up Woolwich guns; the letter B refers to the second layer of metal in each case, but the positions happen to be at opposite ends of the barrel.

described with a longer radius than the corresponding curved portion at the bottom of the case, so that a space is left to prevent the barrel from acting as a wedge, and thus splitting the cast-iron case. When properly fitted, an iron collar is screwed into the muzzle, against a shoulder on the A tube, which prevents the latter from moving forward; and a pin is screwed in underneath which enters about half an inch into the barrel and prevents it from turning round. The muzzle is then faced, and the bore lapped out and rifled. The rifling has a uniform twist of 1 turn in 40 calibres in all these converted guns, but the form of groove differs in the 80 and 64-prs. Rifling.

This class of gun is vented in a peculiar manner. The vent-patch (if any) is removed, and in the case of the 8-inch gun the old vent is closed up with a wrought-iron plug, and a new hole is prepared for the bush a little further from the breech end. All converted R.M.L. guns are permanently vented before proof with a through bush of hardened copper, which is screwed through the case, barrel, and cup; this is perpendicular to the surface of the cup in the gun of 71 cwt., but in the same position as the old bush in the 80-pr. and 64-pr. of 58 cwt. The method of venting will be described in Part IV, being exactly the same as the operation of re-venting on service. Venting.

These guns are proved by firing two rounds, the charge of powder being 25 per cent. greater than a service charge, and the projectile being a solid cylinder of service weight. The expansion of the bore must not exceed certain limits; no part before proof is allowed to be more than ·02 inch under gauge, or more than ·04 over gauge after proof. Proof.

The guns are examined after being fired in the usual manner by the water test, gutta-percha impressions, and gauging. Owing to defects in wrought iron, they not unfrequently fail to pass proof, and failure generally occurs in the cup which closes the end of the breech. In this case the barrel is forced out of the gun by hydraulic pressure applied at the breech, the nozzle of the pipe being fixed into the gas escape channel, which has to be enlarged for that purpose. The expansion of the coiled iron is made evident by the difficulty sometimes experienced in extracting the barrel, and occasionally it has been found necessary to bore out the tube in a lathe. Water-test and G.P. impressions. Failure.

The operation of lining is similar to that applied to all rifled guns, the old line of metal (when marked) being generally found quite correct. The vertical line on the face of the muzzle is extended over the cast-iron case, so as to show any shifting of the tube if that should ever take place. Lining.

The adjustment of sockets for sights is also conducted in the same manner as for other rifled guns; but the sockets for the fore-sight, instead of being let down into the gun, are attached to the exterior by means of brackets and screws. Sight sockets.

A few matters of detail must now be pointed out in connection with each nature of these converted R.M.L. guns. Details concerning each nature of gun.

64-*pr. Guns.*

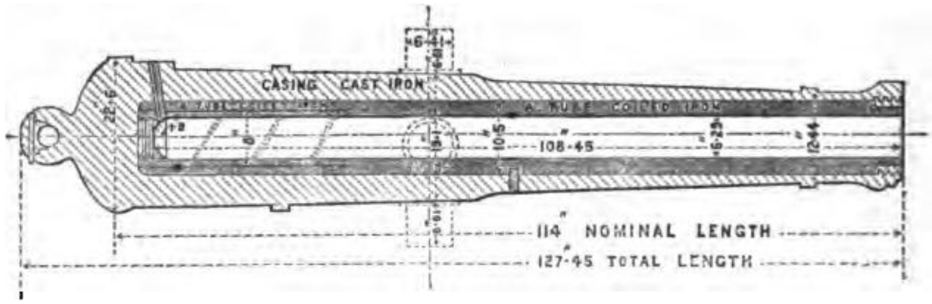
In the 64-pr. guns the groove of the rifling is of plain section, being the same as the deep portion of the shunt groove in the early 64-pr. built-up guns. They fire the same projectiles, but only with an 8-lb. charge. Plain groove.

The guns of 58 cwt. are centre-sighted. Before 1877 they were supplied with only two sights, viz.: a fore-sight of the drop pattern, and a gun-metal hexagonal hind-sight with a plain head; but since that date they have been provided with a muzzle-sight in addition: this is a small steel sight (the same as that used for the 9-pr. L.S. guns) fixed in a recess which is cut in the swell of the muzzle. Centre-sighted.

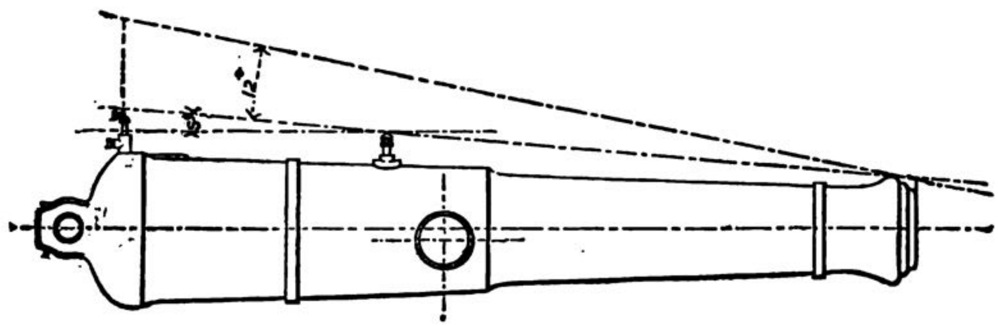
CHAP. V.

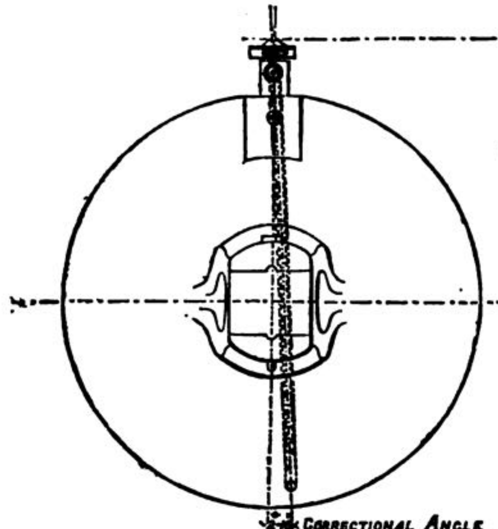
64-pr. 58 cwt.

64-PR. 58 CWT.

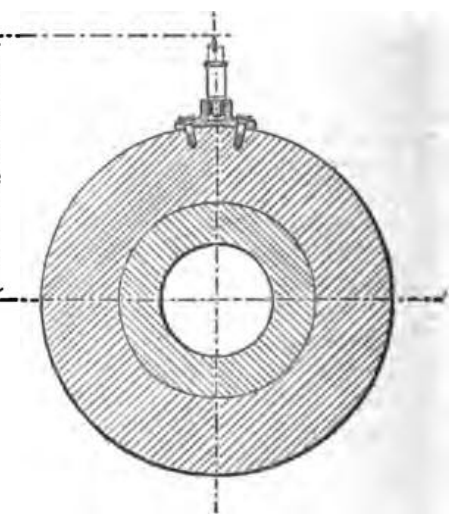


GENERAL ARRANGEMENT OF SIGHTS.

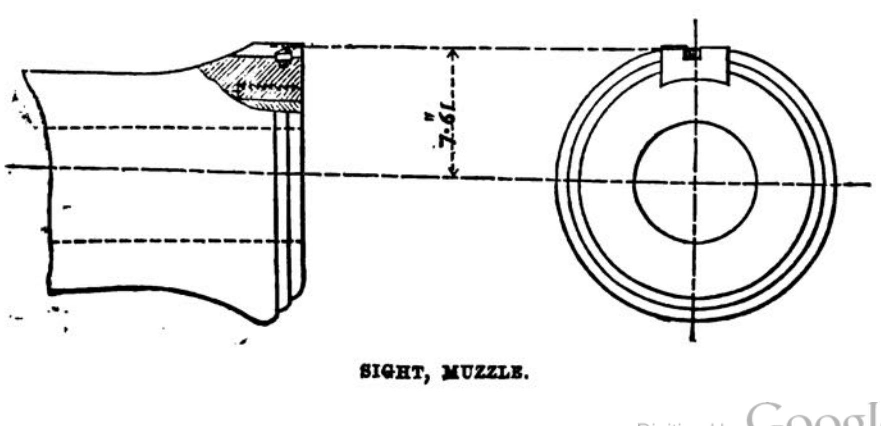




SIGHT, CENTRE HIND.



SIGHT, CENTRE FORE.



SIGHT, MUZZLE.

The present pattern of hind-sight is graduated to 12°, and it is fitted with a cross head and leaf for deflection.

Clearance angle and correction for drift.

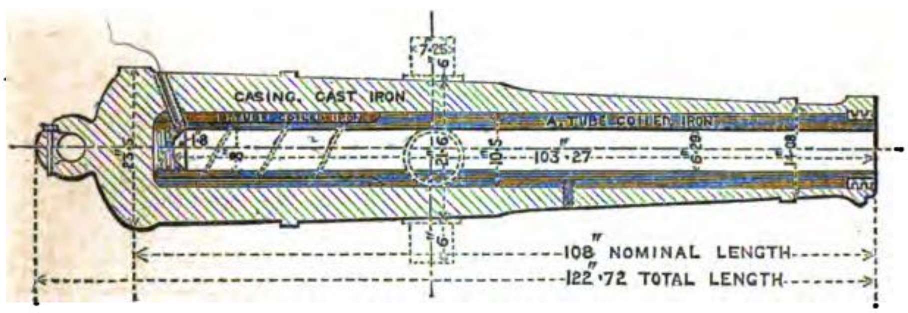
The clearance angle is 5°; and the angle for correction of drift 2° 16′.

It may be observed that the fore-sight is not placed in the centre of the muzzle; this is due to the angle of attachment of the hind-sight; for when raised to the clearance angle the notch is carried to the left, and the line of sight then passes to the right of the line of metal at the muzzle.

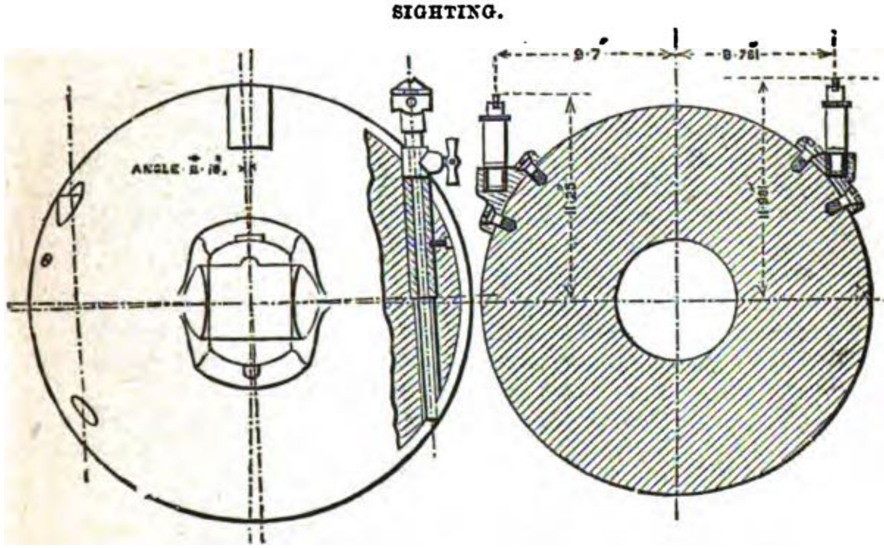
These guns are only used for L.S.

64-pr. 71 cwt.

64-PR. 71 CWT.



SIGHTING.



The 64-pr. of 71 cwt. was at first issued to sea service only, the guns being supplied with all S.S. fittings; but now the Navy are beginning to return them to store, and they will be available for general service.

Rifling and sighting.

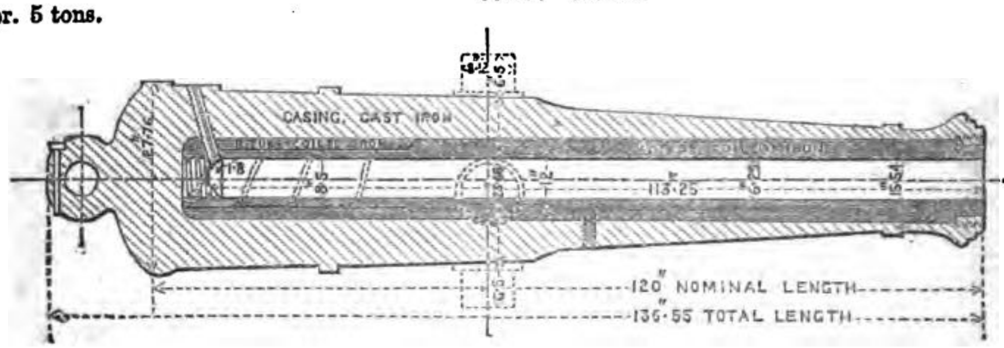
The rifling in this case is the same as in the 64-pr. of 58 cwt., and the angle of sighting is the same, but these guns are side-sighted. The trunnion sights are of the drop pattern, but higher than usual to clear the swell at the muzzle; the tangent sights are similar to those described for heavy R.M.L. guns, being steel bars with a gun-metal head, having a deflection leaf with a S.S. notch, and no slow motion elevating nut.

The correction for drift is 2° 16′ as for the lighter 64-pr. gun.

CHAP. V.

80-pr. 5 tons.

80-PR. 5 TONS.



Sighting.

The 80-pr. is sighted in the same way as the 64-pr. of 71 cwt., but the angle of correction for drift is only 19′, and the sights are not interchangeable.

Rifling.

The rifling is different, the groove being of "Woolwich" section, much broader than the plain groove in the 64-pr. guns. This difference prevents the chance of an accident; for since the calibre is 6·3 inches in all these converted R.M.L. guns, the projectiles might on an emergency be considered available for all, so that a heavier charge might be placed in a 64-pr. gun than the gun was intended to carry. But the wide groove in the 80-pr. gun corresponds with broad studs on the projectile, and this breadth will prevent the heavier shell from entering the bore of any 64-pr. gun.

General Remarks.

General remarks.

For the dimensions, rifling, &c., of the converted R.M.L. guns, see Table XXI, p. 212, which includes all natures of R.M.L. guns in the service.

The sights, fittings, and stores will in like manner be found in Table XX, p. 173, and the latest pattern of hind sights in Table XVIII, p. 148.

Stores.

The following stores are used with these guns:—

Bearer, shot or shell.—For the 80-pr. only.

Brackets, right and left.—These are made of gun-metal to contain the sockets for drop-trunnion sights; they are attached to the 80-pr. and 64-pr. of 71 cwt. by fixing screws, to avoid making a large hole in the cast-iron gun. They must be removed prior to transport.

Bracket, centre-fore-sight.—This is similar to the foregoing brackets, but issued for the 64-pr. of 58 cwt. only; it is fixed in the same manner, and must be removed from the gun during transport.

Clamp, moveable, for tangent sight.—This is required for the 80-pr. and 64-pr. of 71 cwt., which are the two side-sighted guns.

Lanyard guide.—This is of universal pattern. All S.S. guns are prepared for this fitting; the holes are protected by preserving screws, and they are situated to the right rear of the vent.

Machine, hand rifling.—This is common to all the converted guns, but the files must be made to correspond with the form of groove in the 80 or 64-pr. gun.

Pin, friction tube.—This is affixed for S.S. only, but a hole is drilled in all guns to the left front of the vent for the pin to be screwed in when required.

Pricker or priming iron.—To prick the cartridge and clear the vent. It must be 17 inches in length for all these guns.

Screws, firing.—Two for each bracket.

Screws, preserving.—One for every hole which is tapped and threaded

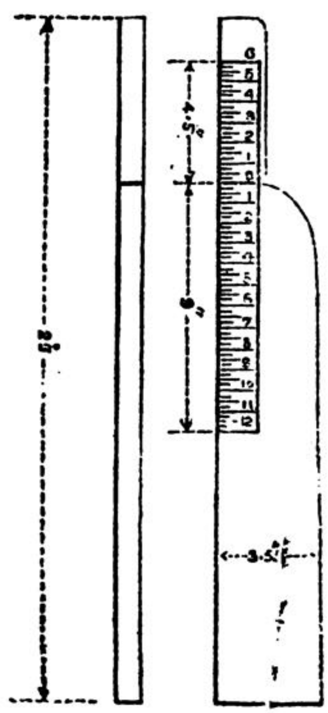
in the gun; viz.: for the fixing screws when the brackets are removed, and for the guide-plate and friction tube pin when the guns are in use for L.S.

Socket, metal, with set screw.—For the 64-pr. of 58 cwt. only. It is let into the breech to receive the centre-hind-sight, and secured by a screw; this must be removed during transport.

Spikes, common and spring.—The common spike is of universal pattern. The spring spikes for 64-pr. guns must be from 9·2 to 9·8 inches in length. The length is measured from the head to the top of the spring. There is none to suit the 80-pr. gun.

Wood side scale.—Of the same pattern as for the S.B. guns from which these rifled pieces have been converted (see Table XIX, p. 152). These are only required for S.S.

WOOD SIDE SCALE.



Wrench, friction tube pin.—To fix or remove the pin, guide-plate, or any of the screws.

For the ballistics of R.M.L. converted guns, see Table XXII, p. 214, at the end of previous chapter.

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PART II.

CHAPTER VI.

R.M.L. HOWITZERS.

Ordnance for indirect and high angle fire.—Rifled howitzers proposed in 1864.—The 8, 9, and 10-inch experimental howitzers.—Introduction of the 8-inch 46 cwt. in 1872, and of the 6·3-inch in 1878.—Manufacture of 6·6-inch and 8-inch of 70 cwt.—Details of construction, sights, fittings, and stores for each nature of howitzer.—General remarks.—Table of dimensions, rifling, &c.

History of the introduction of rifled howitzers.

HOWITZERS were formerly employed in the days of S.B. ordnance for curved or indirect fire, and although no similar pieces were manufactured in the early days of rifled artillery the subject of their introduction engaged the attention of several committees. Rifled mortars were tried as long ago as 1853, but without much success; for these pieces were only capable of being fired at fixed angles of elevation, involving a variation of charge for every range.

Many suggestions were made and several experimental pieces were tried, but no definite action was taken until 1864, when Sir J. Burgoyne called attention to the great value of indirect fire against bomb-proofs, &c., and to the urgent necessity of improving the range and accuracy of existing ordnance provided for this kind of service. The Ordnance Select Committee then proposed that a heavy rifled howitzer should be made, capable of being fired at all angles of elevation up to 30°. Three 68-pr. carronades were rifled accordingly, and the success of the experiments carried out with these pieces led to a 32-pr. bronze block being bored up to a calibre of 6·3 inches and rifled to take the 64-pr. projectiles. This experimental howitzer gave excellent results, and it was proposed to add a piece of this kind to the equipment of a siege train.

64-pr. howitzer.

Further experience was gained during the wars of 1866 as to the power and advantage of high angle fire from rifled artillery, and the Ordnance Select Committee then reported that the matter was ready for decision without further experiments; so in 1867 it was decided that an 8-inch rifled howitzer should be made, the weight of which should be about 50 cwt. Designs were submitted from the Royal Gun Factory for rifled howitzers of 8, 9, and 10-inch calibre, and some of each were manufactured as experimental pieces.

8, 9, and 10-inch experimental howitzers.

In 1870 a committee was appointed to consider whether it was advisable to convert on the Palliser system a certain number of the 13-inch S.S. mortars, and also to report on the results already obtained with the experimental howitzers. The rifled mortars proved unsatisfactory, so the idea of converting them was abandoned. Further experiments, however, were carried out with all the howitzers, and in 1872 it was decided that the 8-inch should be recommended for service. A number of these pieces, weighing 46 cwt., were consequently made

8-inch, 46 cwt.

in 1873-4; they were constructed of wrought iron and steel and rifled like the 8-inch R.M.L. guns on the "Woolwich" system, with four grooves but with a uniform twist.

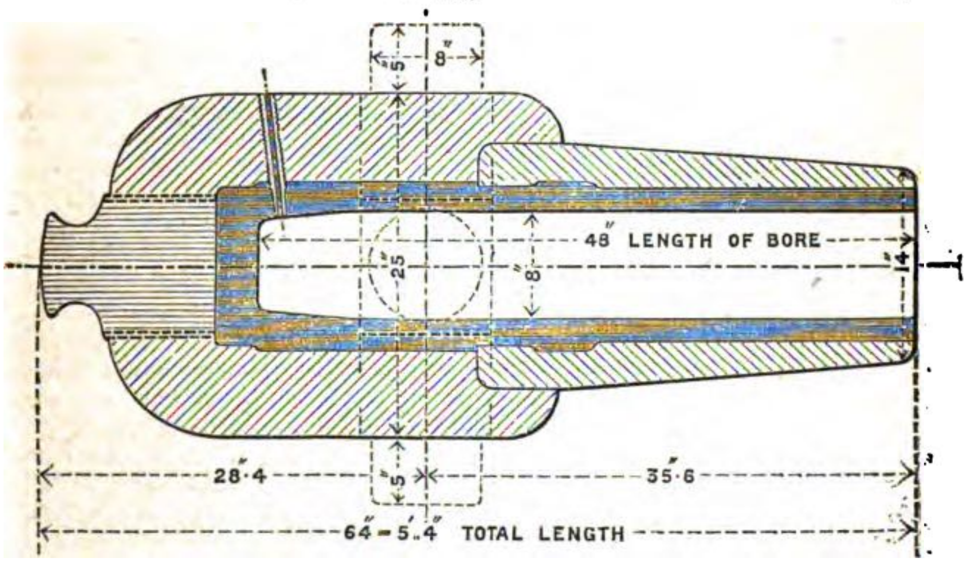
6·3-inch. In 1874 this committee, being anxious to try a lighter nature of howitzer, proposed that one should be made of 6·3-inch calibre, corresponding with the 64-pr. guns. After considerable trial a piece of 18 cwt. was adopted in 1878, and the rifling was changed to the Maitland muzzle-loading system, this piece being the first in which studless projectiles were used with a rotating gas-check attached to the base.

Longer howitzers, 6·3 and 8-inch of 70 cwt. These two natures of howitzers are exceedingly short, especially the one of 8-inch calibre. In 1876, when it became fully recognised that length was essential to power, two new designs were put forward for longer and heavier pieces; at the same time the 6·3-inch calibre was exchanged for 6·6, so as to increase the capacity of the shell. A large number of both these natures were ordered and their manufacture proceeded forthwith; but it was afterwards suspended for two or three years pending a decision on the question of rifling: experimental pieces were issued to Shoeburyness, but the completion of the order for service was not sanctioned until 1880.

8-inch howitzer, 46 cwt. § 2507.

8-INCH. 46 CWT. MARK I.

Scale, $\frac{1}{18}$.



This, as stated already, was the first rifled howitzer introduced into the service, and its manufacture may be said to have commenced about 1872.

Construction and details. It is made of wrought iron and steel, and in construction it is similar to the designs of R.M.L. guns of that date. It is built up of only four parts, viz.: the barrel, B-tube, jacket, and cascable. The end of the bore terminates in a cone of considerable length.

Twist of the rifling. The rifling consists of four grooves, their dimensions being the same as in the 8-inch R.M.L. gun; but the spiral in this case is a uniform twist of 1 turn in 16 calibres. This difference in twist was rendered necessary by the shortness of the bore. The projectiles for the gun and howitzer consequently differ in the front row of studs; the large stud on the howitzer shell, which is adapted to uniform twist, would jam in the bore of a gun with increasing twist, so the projectiles are not interchangeable. The grooves are widely splayed at the muzzle.

Vent. The howitzer is rear-vented 1·75 inches from the end of the bore, the vent channel being inclined towards the breech at an angle of 6° 3′ with the vertical.

Quadrant planes. Three planes are cut on the upper surface of the piece for the use of quadrants in giving elevation up to 30°.

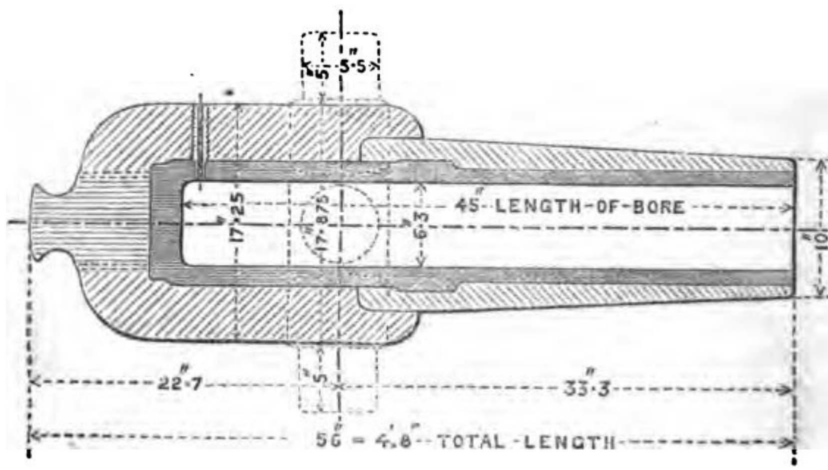
Sights. All howitzers are furnished with cross-bar sights for reverse and forward laying, the hind-sight being set perpendicularly to the axis on account of the varying charge. Any requisite deflection can be given on the sliding cross-bar, which has an extra length of scale to the left.

This 8-inch howitzer at first was centre-sighted with muzzle, centre, and tangent-scale sights; some pieces may still be found sighted in this manner, but the system is obsolete.

6·3-inch howitzer, 18 cwt. §

6·3-INCH. 18 CWT. MARK I.

Scale $\frac{1}{15}$.



Employment. This is the smallest howitzer in the series; it is one of the pieces belonging to a light unit of siege train, and a large number have also been sent out to India for use in the land forts of that country.

Construction. The manufacture of this nature commenced in 1874, but none were completed till 1878, when the question of rifling was settled. Its construction is similar to that of the 8-inch, but the proportions are different. The end of the bore is cylindrical, rounded off with a radius of 1 inch, and the muzzle is slightly bell-mouthed.

Rifling. The rifling consists of twenty grooves of M.M. section, 0·1 of an inch deep and 0·5 broad. The twist increases from 1 turn in 100 calibres to 1 in 35 at the muzzle. The rifling extends to a point 5·3 inches from the bottom of the bore, and the end of each groove is hammered up, so as to terminate as abruptly as possible; this forms a stop for the projections on a gas-check and regulates the capacity of the chamber. In a few of the first that were made the rifling extends 2·8 inches further, but the depth of the groove beyond this point is only ·05 of an inch, so the projectile would be stopped at the same distance in all.

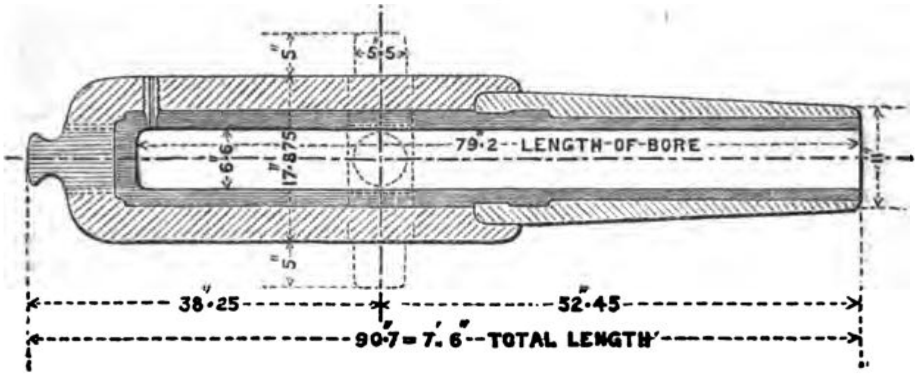
Sights and quadrant planes. The sighting and quadrant planes are the same as for the 8-inch of 46 cwt. and the remark as to centre-sighting originally also applies to the 6·3-inch, but it was very soon cancelled in this case; the first issue only were supplied with these sights.

This howitzer may be fired at any angle of elevation up to 40°, either on wheels or on the bed of the carriage dismounted.

6·6-INCH. 36 CWT. MARK I.

Scale, $\frac{1}{24}$.

6·6-inch howitzer, 36 cwt. Mark I. § 4012.



Details.

A supply of howitzers of this nature was manufactured in the year 1877, but they were not completed and rifled until 1880. They differ from the 6·3 chiefly in length. The rifling is of the same description, but not quite so deep; there are twenty grooves, 0·05 of an inch deep and 0·7 wide. The twist increases from 1 in 94 calibres at the breech to 1 in 35 at the muzzle. These howitzers will mainly be used in the medium units of siege train.

6·6-INCH. 36 CWT. MARK II.

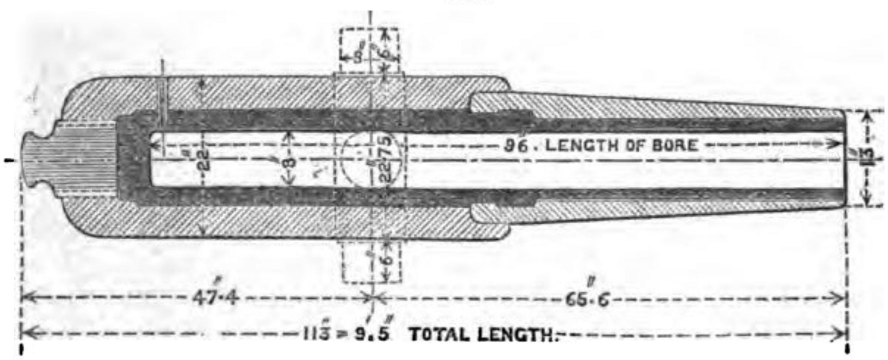
Mark II, § 4636.

A second Mark of this howitzer has been designed and approved for future manufacture. This only differs from the Mark I in material, being made entirely of steel.

8-INCH. 70 CWT. MARK I.

Scale, $\frac{1}{18}$.

8-inch howitzer, 70 cwt. Mark I. § 4011.



Details.

These howitzers were built up in 1876, but, as in the case of the previous nature, they were not completed till 1880. In proportion as well as construction the 8-inch of 70 cwt. resembles the 6·6-inch. They are powerful pieces, and form the chief armament of a heavy unit of siege train. The grooves of the rifling are exactly the same, and so is the twist at the muzzle; but at the breech it commences with 1 turn in 90 calibres instead of 1 in 94, and with larger calibre the number of grooves is increased from twenty to twenty-four.

8-INCH. 70 CWT. MARK II.

Mark II, § 4636.

The Mark II of this nature is similar in construction to the Mark I, being made entirely of steel.

CHAP. VI.

General Remarks.

Marks. The 8-inch of 70 cwt. must not be considered a second mark of this calibre in conjunction with the piece of 46 cwt. All four descriptions of howitzers are separate natures of ordnance, and are all designated Mark I of their kind.

Royal monogram. The royal monogram will be found in this class of ordnance on the chase instead of the breech. This alteration became necessary when a quadrant plane was cut on the breech in the exact place where the monogram will always be found upon guns.

Gas escape channel. Gas escapes are provided in all howitzers in the same manner as in R.M.L. guns; the channel is visible on the right hand top side of the breech.

Points of resemblance. All howitzers are now prepared for cross-bar sights, the two longer natures having sights on each side. They are vented near the end of the bore on account of firing very small charges at times, and (excepting the 8-inch of 46 cwt.) they are all slightly bell-mouthed, their rifling is of the same character, and the twist at the muzzle is 1 turn in 35 calibres.

A table is given on the following page of the dimensions, rifling, &c.

For the sights, fittings, and stores which should be issued with each howitzer see Table XX, p. 173, which contains this information for all natures of R.M.L. ordnance.

TABLE XXIII.—SHOWING DIMENSIONS, RIFLING, &C., OF R.M.L. HOWITZERS.

Nature.	Weight.	Length.				Chamber.			Rifling.		Grooves.			Preponderance.	Remarks.
		Nominal.	Bore.		Rifling.	Length.	Diameter.	Capacity.	System.	Twist.	Number.	Width.	Depth.		
			Inches.	Calibres.											
	cwt.	ft. in.			in.	in.	in.	c. in.						cwt.	
8-inch ..	70	9 2·125	96	12	93·5	8	8	397	M.M.	I. 1 in 90 to 1 in 35	24	·7	·05	nil.	
8 " ..	46	5 1	48	6	35·5	12·5	8	584*	Woolwich	U. 1 in 16	4	1·5	·18	2	
6·6 " ..	36	7 4·5	79·2	12	76·7	5·075	6·6	169·5	M.M.	I. 1 in 94 to 1 in 35	20	·7	·05	nil.	
6·3 " ..	18	4 6	45	7	42·5	5·3	6·3	161·26	M.M.	I. 1 in 100 to 1 in 35	20	·5	·05	nil.	

* This capacity refers to projectiles fitted with gas-checks: when studded projectiles were used they could be rammed a little further down the bore.

PART III.

CHAPTER I.

BREECH-LOADING GUNS.

Breech-loading guns.—The muzzle- *v.* breech-loading question.—Rapidity of fire.—Exposure of men.—Size of embrasure.—Smoke.—Length of gun.—Effect of length on muzzle velocity.—Table for comparison of power in guns of the same weight.—Table for comparison of guns differing only in length.—Risk of accident.—Accuracy of shooting.—Power of guns.—Table for the comparison of power in two M.L. and B.L. guns of similar weight.—Facility for inspection of the bore.—Enlarged powder chambers.—Density of the charge.—Gravimetric density.—Table of experiments to show the effect on ballistics of varying the density of charge.—Manufacturing and other advantages in favour of breech-loading guns.—Methods of closing the breech.—Screw, wedge, and interrupted screw systems.—Précis of the progress of B.L. guns.—Committee on Ordnance, 1879.—E.O.C. guns, 6-inch and 8-inch.—State of manufacture, 1881.—Principles of construction.—Ordnance Committee, 1881.—6-inch Mark II.—Enlargement of powder chambers.—New construction required for slow-burning powder.—9·2-inch Mark I.—Steel guns 8-inch calibre.—12-inch Marks I and II.—4-inch Mark II.—6-inch Mark III.—Report of the Committee.—Coiled iron given up as a material for ordnance.—Steel breech-piece for longitudinal length.—Varieties of construction.—Wire guns.—Obturation.—Table for comparison of certain B.L. guns with M.L. pieces of similar weight.

Rifled artillery.

THE first rifled artillery in our service consisted of breech-loading guns, but after a trial of five or six years this class of artillery was superseded by rifled muzzle-loading ordnance; the cause of their failure, however, lay rather in the imperfections of the system adopted, than in the fact of their being breech-loaders. After a lapse of about fifteen years we were compelled to return to breech-loading guns.

Return to breech-loading guns.

In discussing the merits of this recent change, reverting as it were to a system that had been tried and condemned long ago, the question of expediency must be considered independently of the breech-closing action. It is now clear that the return to muzzle-loading ordnance was really a retrograde step, and that development of artillery power depends upon dimensions in guns, which necessitate their being breech-loaders. As a matter of fact modern guns have little in common with those which were made twenty-five years ago; the material and construction are both very different, and so is the breech-closing action. Many methods of closing the breech have now been invented, and some have passed satisfactory trial, confirmed in one or two cases by use during a quarter of a century; we may therefore assume that if power

CHAP. I.

can be gained by the adoption of breech-loading guns (at least to such an extent as to outbalance the expense of a radical change and some advantages known to exist in muzzle-loading ordnance), a breech-closing system may be found without difficulty to suit the new type of gun, and that this point may be subsequently treated as a mere matter of choice.

M.L. v. B.L.

Briefly stated, the balance of favour will be found to lie between *simplicity* in muzzle-loading guns, and *power* on the side of breech-loaders; but there are numerous incidental advantages acquired by loading at the breech, which taken together add much weight to the arguments in favour of breech-loading guns.

The debatable points are numerous, and in some cases they may be equally balanced, for objections to either system have been overcome by machinery and skilful appliances; but the main question of *power* has led to an unqualified decision by all nations in Europe in favour of breech-loading ordnance.

Some of the points may be alluded to here, but space will not permit of any lengthened discussion.

1. *Rapidity of Fire.*

Rapidity of fire.

Rapidity without range and accuracy is comparatively of little importance. Machine guns supply this element in the nature of fire for which they are suited. In the case of heavy guns, or even of field guns in the open, it is only with case shot at short range that rapidity of loading by itself can ever be of much practical value. Experiments, however, have shown that there is really no difference in the time required for working an M.L. or B.L. field gun, and that rapidity of fire will generally depend on the position and circumstances surrounding a gun, rather than upon the question of loading at the muzzle or breech. (See Report of Experiments carried out at Oakhampton in September, 1880.)

2. *Exposure of Men.*

Exposure of men.

This point must be considered separately for guns in the field and for those which are mounted on permanent works.

In open ground, or behind such cover as may be hastily thrown up in the field, a breech-loading gun will always have an advantage. In siege operations it is possible that a muzzle-loading piece, when mounted on a disappearing carriage, would bring the gunners close to the parapet, and therefore in a position of safety; but this would only occur with the use of special and complicated carriages: when firing through any embrasure, a B.L. gun would help to fill up the opening.

In all permanent works a breech-loading gun would not only close the port against an enemy's fire, but it would cause the loading to be conducted in safety. In a turret or cupola, the gun with all its machinery, and the detachment working the gun, would thus be fully protected, while muzzle-loading guns would require a second turret for the loading arrangements, and injury to this would throw the guns out of action as much as if they were disabled themselves.

3. *Reduced Size of Embrasure.*

Size of embrasure.

This point would refer only to heavy guns when mounted in permanent works, for in any siege operations in future we may presume that embrasures will be avoided altogether if possible. The splay of embrasure must depend on the amount of training to be given to the

gun, and this would be much the same, whether the piece were of M.L. or B.L. description; length, however, in a gun will save the revetment from much damage caused by the blast of the gun itself. Iron shields have been adopted to lessen the breadth of the port, and muzzle-pivoting carriages have been introduced to reduce the size of this opening, but these carriages might be used for either description of ordnance: hydraulic loading outside may be resorted to also for muzzle-loading guns; but none of these arrangements confer any advantage on the gun: on the contrary, they form additional intricate appliances, and efficiency depends on their being always in order for action. Practically, therefore, this point does not much affect the question at issue.

4. *Smoke.*

Smoke.

It has been said that in opening the breech after firing, great volumes of smoke would fill the casemate, turret, or ship, which might suffocate and blind the detachment. This argument, however, is really in favour of B.L. guns, except in the case of turrets supplied with loading arrangements outside. A muzzle-loading gun must recoil so as to bring the muzzle inside the work, and with it a large portion of the smoke; and in loading the whole of the smoky residue is pumped into the casemate; but with breech-loading guns the muzzle may be kept always outside, and if time be allowed the smoke will escape more or less freely, depending chiefly on the direction of wind. If there is no wind, or none at least from the front when the breech is opened after firing a round, the greater part of the smoke will escape by the muzzle, owing to the elevation which is given to a gun, and conveyed straight out. If necessary, artificial draught could be easily applied, but the need of such an arrangement has not yet been proved by experience.

5. *Length of Gun.*

Length of gun.

Length must be treated from two different points of discussion. Considered simply as a question of *size*, no doubt a long gun may be found inconvenient in existing forts and emplacements; but with the growth of artillery power (in foreign nations as well as our own), the forts and ships must be built to meet the requirements of national defence.

In the matter of recoil, as already pointed out, length becomes a serious objection to muzzle-loading guns of large size; for either the recoil must be great to enable the loading to be conducted within the turret or fort, or else loading arrangements must be separately provided outside. With manual labour again, great length must involve great exertion, and this is felt even with guns of moderate size; but with a breech-loading piece the distance for ramming the charge can never be great: ordinary power will suffice, and less space is required, for the gun need not recoil so as to bring the muzzle inside the port.

The effect of length on M.V.

Length again must be considered in connection with *power*, and this is the more important side of the question. Recent experiments have clearly established the fact that large charges of slow-burning powder, with adequate length in the bore for combustion of the charge, give higher velocity to a shot than a violent powder in a short gun containing a similar weight of metal.

Some results of firing M.L. and B.L. pieces of approximately the same weight, but differing greatly in length, are brought together for comparison of power in a Table which is given on page 232.

With regard to this table it may possibly be urged that the comparison is drawn between guns of different type; but similar results

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will be found in experiments conducted with guns of exactly the same nature which differ only in length. This will be seen from the reports of firing some 8-inch and 9·2-inch B.L. guns, which are given on the following page. The calibre, rifling, capacity of chamber, projectile, weight, and density of the charge, are exactly the same for the long and short guns of each kind, but the results differ considerably.

Hence within certain limits, which must vary with the nature of powder, length of bore adds directly to muzzle velocity, and it therefore contributes very largely to accuracy of shooting and power.

6. *Risk of Accident.*

Risk of accident.

This point can only be determined by experience, and the experience of B.L. guns has been too short as yet to speak very confidently on the subject. There have been accidents with both classes of ordnance. With muzzle-loading guns men's arms have been blown off in loading, and thumbs split in serving the vent; double loading is possible and may cause accidents of importance. On the other hand, with breech-loading guns a few accidents have happened from the breech being improperly closed, which were probably due in each case to insufficient training of the men, but these occurred when the guns were quite new and no doubt imperfectly known. Double loading is impossible with B.L. guns; and it has been found practicable to add many safeguards against accidents due to faulty drill. Imperfect closing of the breech is the only risk entailed by the adoption of breech-loading guns; and this may be considered almost impossible now, for various automatic arrangements are added to the breech action itself to prevent the guns being fired until the breech is properly closed.

7. *Accuracy of Shooting.*

Accuracy of shooting.

This most important element in artillery fire has been practically settled in favour of breech-loading guns. The range and accuracy returns from Shoeburyness leave no doubt on this point.

Accuracy of *line* depends mainly on the centering of the projectile in the bore, which is much more perfectly attained in a breech-loader than in a muzzle-loader, where windage must exist.

Accuracy of *range* depends also on the foregoing, but more particularly on uniformity in muzzle velocity, which is again dependent on uniformity in the combustion and density of the charge. Here the resistance offered by the driving-band of the B.L. projectile acts as a very efficient regulator and assists greatly in securing these important conditions.

8. *Power of Guns.*

Power of guns.

Power may be estimated in various ways according to the object in view. In field artillery the greatest effect of shrapnel shell is specially studied; with siege ordnance common shell will prove most destructive, while in heavy guns it is only in perforating armour-plate that they are required to put forth their full power. From an artillery point of view, heavy guns are the principal weapons of war for offensive or defensive purpose, so the penetration of wrought-iron plate will furnish the best standard for comparison of power in heavy guns of the present and past.

TABLE XXIV.

TABLE FOR COMPARISON OF GUNS OF SIMILAR WEIGHT, BUT DIFFERING GREATLY IN LENGTH.

Gun.	Weight.	Total Length.	Charge.		Muzzle.		Range with 2° Elevation.	Perforation at 1000 yards.
			Powder.	Projectile.	Velocity.	Energy.		
		inches.	lbs.	lbs.	f.s.	f.t.	yds.	ins.
16-pr. M.L...	12 cwt.	78	3 R.L.G.	16	1855	208	1145	3·0
22-pr. B.L. (Expl.)	„	107·5	7½ P.	22	1735	458	1732	5·2
40-pr. (II) M.L.	35 cwt.	120	7 R.L.G.	40	1880	528	1185	4·0
5-inch (II) B.L.	38 „	139·5	16 P.	50	1780	1098	1880	6·9
9-inch (V) M.L.	12 tons	156	50 P.	258	1420	3607	1480	10·2
8-inch (IV) B.L.	15 „	254·5	{100 Prism[1], black}	210	2030	5973	2500	14·2
12-inch (II) M.L...	25 tons	182·5	85 P.	615	1288	7074	1250	11·9
10-inch (II) B.L.	29 „	342·4	{250 Prism[1], brown}	500	2100	15310	—	21·2

TABLE XXV.

TABLE FOR COMPARISON OF M.V. IN B.L. GUNS DIFFERING ONLY IN LENGTH

Gun.	Weight.	Length of bore.	Projectile.	M.V.			Remarks.
				100 lb. Prism[1].	110 lb. Prism[1].	115 lb. Prism[1].	
8-inch B.L., Mark I	11 tons	203·9	lbs. 210	1960	1993	2049	
" " " II	"	235·9	"	2030	2066	2117	
				165 Prism[1].	170 Prism[1], brown.	200 C[2].	
9·2-inch B.L., Experimental ..	17 tons*	195·4	380	1738	1787	1778	* Muzzle shortened.
" " Mark I	22 "	239·2	"	1845	1953	1955	
" " " II	21 "	261·2	"	1901	2009	2040	
" " " III	24 "	289·8	"	1956	2050	2086	

This kind of power depends on the striking energy and form of the shot, but sometimes it is more convenient, without very great error, to take the "muzzle energy" imparted to the projectile as a measure of power; with shot of similar dimensions and the same weight the "muzzle velocity" will furnish a direct and simple means of comparison.

A table will be found at the end of this chapter, which (together with those already given) will show the enormous increase of power in modern artillery, and the great superiority in perforation attained by the breech-loading guns. (See p. 244.)

This development of power is mainly due to an increase in the charge of powder, and this can only be given with full effect (without inordinate weight in the piece) by the use of slow-burning powder in guns of very great length: then to reduce the length of the cartridge and avoid wave pressures in the gun, the chamber must be greater in diameter than the bore of the piece, and consequently the guns must be made for breech-loading. Moreover, the rifling which is suitable for breech-loading guns, and the corresponding arrangement on the shot which enables it to follow the twist, both assist in promoting velocity and steadiness of flight; so these points also contribute towards the development of power which has followed the adoption of a breech-loading system.

9. *Durability and Expense.*

Durability and cost.

Durability is generally based on the number of rounds that constitute the life of a gun, but this is hardly a fair standard of comparison when the work stored up in each round is altogether ignored. For number only, no doubt existing ordnance of the muzzle-loading class could fire more rounds than B.L. guns of modern description, but with equal demand on their fabric the latter would last much the longer. If the comparison were based on the energy of projectiles thrown by the gun, the total destructive effect produced by a breech-loading piece would far exceed that of its companion muzzle-loading gun.

The first cost of a B.L. gun is undoubtedly greater than that of a M.L. piece of like weight, and the breech fittings may have to be renewed; but in repair of the barrel, where the chief wear of the gun occurs, the advantage lies on the side of breech-loaders. So it remains to be proved by experience whether the cost is actually greater when taking into consideration the whole work done by the gun, which depends on its power of endurance with an ordinary amount of repair. Granting, however, that the first outlay is greater, and possibly the eventual cost of the gun, the certainty of warding off an attack or of speedily effecting a breach will have to be thrown into the scale on the side of breech-loading guns, not to speak of the immeasurable economy which would of course be derived from success.

10. *Facility for Examining the Bore.*

Facility for inspection of the bore.

Any breech-loading system will offer the advantage of easy inspection of the bore during action, and facility for making a thorough examination of the gun. This becomes more important every year with the increasing weight of the charge and progress of artillery power. Large charges must necessarily have great effect on the metal of a gun, and accidents in the future may perhaps be more serious than those of the past. By freedom of inspection the damage caused by explosion of shell may be discovered at once; while the work of re-

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storing the rifling when damaged, or any other repair, can be carried out with greater facility from the convenience of light in the bore and closer contact with the operation in hand.

11. *Enlarged Powder Chamber.*

Enlarged powder chamber.

With magnitude of charge it becomes necessary to place a limit on the length of the cartridge. Long cartridges are most inconvenient for storage, and by extending too far down the bore when rammed home in the gun they place the projectile in an unfavourable position; the length of the bore is practically shortened, and a gun might be fired under conditions which were never contemplated in its construction. But by far the chief objection to a very long cartridge is the risk of setting up *wave-pressures* in the gun, and when dealing with very large charges these pressures might approach the limit of strength in the piece.

By increasing the diameter of the chamber shorter cartridges may be employed, while the requisite thickness of metal can be made up in external dimensions. With muzzle-loading guns this enlargement cannot be carried to any great extent, for no method has yet been discovered of making a long cartridge expand properly into a chamber of much greater diameter than itself. With breech-loading guns there is no difficulty, provided that the entrance to the chamber is as large as the cylindrical part; the chamber then may have any capacity, and the cartridge can be made to suit its dimensions.

12. *Density of Charge.*

Density of charge.

The importance of studying the density of the charge was not fully appreciated in the early days of R.M.L. ordnance, nor could the density be regulated with precision as now managed with breech-loading guns.

Gravimetric density.

The density of the charge must not be confused with the density of the powder, though the one is to a certain extent practically dependent on the other when the chamber is filled as full as possible. The density of the charge is distinguished by the term "Gravimetric Density" (written G.D.), and is measured by the ratio of the weight of powder in a given space of chamber, to that of the same volume of water. Thus it is obtained by dividing the number of cubic inches contained in the chamber by the number of lbs. allowed in the charge, and dividing this quotient again into 27·73, which is the number of cubic inches occupied by 1 lb. of water at a temperature of 62° Fahr. Hence:—

$$\text{G.D.} = \frac{27{\cdot}73}{\dfrac{\text{volume of chamber}}{\text{lbs. of powder}}}$$

For if V = volume of chamber,
W = weight of powder in the charge,
and 27·73 = volume occupied by 1 lb. of water,

the weight of water equal to volume V is $\frac{V}{27{\cdot}73}$ lbs., and the ratio of the weight of powder to this is—

$$\frac{W}{\dfrac{V}{27{\cdot}73}} = \frac{27{\cdot}73}{\dfrac{V}{W}}$$

For example, when the powder is allowed 30 cubic inches per lb., the G.D. $= \frac{27{\cdot}73}{30} = {\cdot}924$.

TABLE XXVI.

Experiments carried out with 12·5-inch R.M.L. guns to show the change in ballistics with varying density of charge.

Series.	Charge. Power.	Charge. Density.	Projectile.	M.V.	Mean pressure in chamber.	Remarks.
	lbs.	c. i. per lb.	lbs.	f.s.		
(1) Increasing charges in a chamber of constant capacity.	130 P.[2]	40·45	810	1268	11·7	Result:— Total increase of velocity, less than one-fourth. Total increase of pressure, nearly double.
	140 „	37·58	„	1340	14·6	
	150 „	35·08	„	1392	16·6	
	160 „	32·86	„	1459	18·3	
	170 „	30·95	„	1507	19·8	
	180 „	30·00	„	1544	20·8	
(2) Increasing charges with constant density, chamber varying.	160 P.[2]	30·00	„	1481	21·8	Result:— Velocity increasing with the charge. Pressure practically constant.
	165 „	„	„	1496	21·8	
	170 „	„	„	1501	21·8	
	175 „	„	„	1526	21·1	
	180 „	„	„	1541	22·7	
	185 „	„	„	1541	22·1	
(3) Unchambered and chambered gun	210 Prism[1]	$\frac{24·5}{1·132}$	„	1540	26·2	Result:— Velocity nearly equal, but
	„	$\frac{29}{·956}$	„	1535	18·9	Pressure widely different.

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A table has been given in an earlier part of this book (see page 106) from which the gravimetric density of a charge may be found corresponding to any volume in cubic inches per pound, *i.e.*, volume ÷ weight, as above.*

With regular density the muzzle velocity is equally uniform, and the shooting of the gun is then accurate. Now it was discovered some years ago with muzzle-loading guns, that a reduction of density lowered both the velocity imparted to the shot and the pressure exerted in the gun, *but not in equal proportion.* This was a key to development of power in guns. A small reduction of density greatly lowered the pressure, so that larger charges could then be employed, which not only restored the velocity, but increased it almost in proportion to the increase of charge.

Some experiments carried out with 12·5-inch R.M.L. guns may be quoted to show the effect of varying the density of charge, with and without increase of weight. (See Table XXVI, which is given on the previous page.)

From these experiments it is evident that while P^2 powder is used, either (1) pressure can be reduced without loss of velocity, which implies a possible reduction of weight in the gun; or (2) velocity can be increased without increase of pressure, and this means development of power. With a change of powder still further advantage was gained; the density for maximum effect will vary with the rate of combustion.

In new breech-loading guns the density of charge is carefully studied, but owing to the introduction of slow-burning powders, it is no longer essential to keep the density low. Regularity must be maintained, but the gravimetric density may sometimes be actually higher than it was with muzzle-loading guns when the charge was rammed home with full force. The chamber is now filled almost completely with the powder best suited to the gun; slow combustion creates moderate pressure, while the effect of the gas in impelling the shot is maintained with accelerating force over the whole length of bore, and a maximum velocity is reached at the moment of quitting the muzzle.

13. *Manufacturing Advantages, &c.*

Manufacturing advantages.
Trepanning.

Among the secondary points in favour of breech-loading guns we may mention the saving of material effected by trepanning instead of boring out the steel tubes. The solid cylinders removed by this process often have a considerable value, amounting perhaps to hundreds of pounds, while the operation is actually cheaper than boring out the metal in chips. Trepanning cannot be applied to the barrel of a muzzle-loading piece, but with B.L. guns made of steel every part can be bored out in this manner without much waste of material.

Rifling.

Again, the grooves of the rifling in B.L. guns can be made of less depth than in any kind of muzzle-loading piece, even since the adoption of a polygroove system with gas-checks for giving rotation to the shot. With shallow grooves the strength of the barrel is less reduced by the

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* In writing the expression for the density of a charge, it is usual to give both the quotient first obtained, and its value referred to water as obtained from the table; thus for the example given above, the density would be written—

$$\frac{30.}{\cdot 924}$$

meaning that 30 is the number of cubic inches per lb. in the charge, and ·924 its density referred to water.

rifling, the number distributes the strain, and resistance in the bore can be regulated by the material or thickness of the rotating band.

The effect of varying the resistance in the bore, and the necessity for having some resistance to develop pressure on the base of the shot, is shown by the following experiments which were carried out in 1882:—

Gun.	Charge.		Projectile.	Resistance.	M.V.	Pressure.
	Powder.	Density.				
4-inch B.L., 13 cwt. ...	4½ P.	$\frac{26 \cdot 66}{1 \cdot 041}$	25	None. Shot loaded from the muzzle.	1000	4·0
" " ...	"	"	"	Moderate. Weak band.	1208	8·6
" " ...	"	"	"	Strong band, service pattern.	1313	11·7

Venting also supplies an argument in favour of breech-loading guns, for removable bushes can be easily adapted to this class of ordnance even in a radial position. By the use of removable vents the operation of bushing with copper is altogether abolished, and reventing on service is reduced to a few minutes' work in changing a movable store. In fact B.L. guns need never be thrown out of action by excessive wear of the vent, for as soon as much erosion is noticed the vent-bush can be replaced by another. Removable vents have been recently fitted to some of the heaviest R.M.L. guns, but the operation of removal in this case takes time, and it requires special implements of a large and cumbrous nature.

Re-lining. A still more powerful reason may now be offered in favour of breech-loading guns, and this is the possibility of their being re-lined as erosion takes place in the bore. With heavy charges (and large charges are necessary for power) the scoring in the bore of a gun will seriously affect the life of the piece. M.L. guns can certainly be repaired with a new barrel, but this repair generally involves also a new tube over the chase, and the gun is in fact half made over again. By the insertion of a new "liner" only in a breech-loading gun the repair is restricted to the part which is actually worn; the extent and thickness of metal removed may be limited to the degree of erosion in each particular case; the cost will be little, and the repair can be soon carried out, while owing to the character of the work it may be repeated as often as necessary.

Summary. From the foregoing discussion it will now be apparent that breech-loading guns are a necessity in the present condition of artillery science. For the development of power, and to keep pace with nations abroad who have been re-arming themselves of late years with more powerful guns, it became necessary to abandon the course to which this country had been committed in 1865, and to which it was compelled to adhere for some time on account of the vast expense of re-arming the vessels and forts. Re-armament also involved the question of building new ships and of re-building some of the forts, for the larger guns of new type cannot be mounted in existing emplacements or on carriages already made for the service. Necessity at last overcame the objection of expense, and with a decision in favour of adopting breech-loading guns, the next question which had to be settled was the particular method for opening and closing the breech.

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Methods of Breech-closing

Three systems only had been considered worthy of application to service artillery in Europe, viz.:—

(1) the screw;
(2) the interrupted screw; and
(3) the wedge.

Screw system.

The screw system has been already employed in this country, and not having proved satisfactory this class of guns had given way to rifled muzzle-loading ordnance. A return to the screw system was naturally out of the question; it was inapplicable to guns even of moderate weight, it required too much time for opening and closing the breech, and it could not be combined with the most approved methods of preventing escape of the gas.

Wedge system.

Wedge guns have found favour abroad, and there are several varieties of the wedge system; but the objections to this class are weighty: it requires great length in the breech, which is the heaviest part of the gun, and the wedge itself is too heavy in very large guns for proper facility in working the piece; while exposure of men at the side to the chance of escape of the gas is a serious objection to any wedge system. The plan adopted by Krupp appears to be an effectual method of closing the breech, and certainly lends itself to strength of construction, but on comparison with the interrupted screw system the latter was found on the whole to offer superior advantages.

Interrupted screw system.

The interrupted screw system had been adopted in many countries abroad, and had passed through satisfactory trial. Guns closed on this plan are lighter and more easily worked than those on any wedge system. This method also possesses the advantage of being suitable for all the known systems of obturation, especially the De Bange which has proved so very successful. A description of the breech-loading gear, and of the methods of obturation in conjunction with it, will be found in a future chapter when dealing with this type of gun.

History and Progress of B.L. Guns.

Précis of the progress of B.L. guns.

The manufacture of new B.L. guns may be said to have commenced as recently as the year 1880, but already this class of ordnance is almost as numerous as that of R.M.L. guns. The history of their introduction is briefly given in the following précis of the progress made during four or five years.

In the Annual Report of the Director of Artillery and Stores for 1878–9 it was pointed out that owing to the increased length of modern guns, breech-loading had become a necessity: and having carefully considered the best known systems in force, such as Krupp's, Whitworth's, the French, and several others, that preference should be given to the interrupted screw.

The Superintendent R.G.F. was then called on to design B.L. guns of this type of about 20 and 40 tons weight.

Committee on Ordnance, 1879.

In June, 1879, a Committee on Ordnance was appointed under the Presidency of the late Major-General S. E. Gordon, C.B., and amongst their instructions it was specially mentioned that they should take up the subject of M.L. or B.L. guns for the service. They first recommended a 12-inch B.L. gun of 43 tons, the design of which was put forward by General Younghusband, F.R.S., then Superintendent of the Royal Gun Factory; subsequently also a 10·4-inch B.L. gun for land service, and a 9·2-inch to compare with 24-c.m. gun manufactured by

Krupp. Approval was given, and these pieces were at once put in hand.

Two other guns of the same type to suit the naval demands were also recommended by the Committee in the same year; both 25-pr. guns, one of 22 cwt. for the use of gun-vessels, and the other of 13 cwt. for the armament of boats and for torpedo defence of large ships.

E.O.C. guns. 6 and 8-inch.

In the meantime two B.L. guns made at Elswick of 8 and 6-inch calibre, were lent by Sir William Armstrong & Co., for trial at Shoeburyness. They proved to be so satisfactory in the summer of 1879, that three more 6-inch were purchased, and afterwards an order for fourteen additional guns of this type was given to the Firm, for the armament of H.M.S. "Rover."

The 8-inch.

The 8-inch gun also was bought, and trials were carried out by the Committee; this gun became unserviceable after firing 350 rounds through wear of the bore, and it was returned to Elswick for the purpose of being re-lined. It has since fired a large number of rounds, but no more 8-inch guns of this type were either purchased or made.

"Angamos" accident.

Both the 6 and 8-inch E.O.C. guns were constructed of steel barrels reinforced with wrought-iron hoops. An 8-inch gun of this character afterwards failed on board the Chilian vessel "Angamos" from want of longitudinal strength. Accordingly severe tests were applied to some of the 6-inch B.L. guns that had been purchased for H.M.S. "Rover": the guns stood their trial and were afterwards issued for service. In the meantime another design had been adopted for the manufacture of similar guns in the Royal Gun Factory.

State of manufacture in March, 1881.

In March, 1881, when the Committee on Ordnance was dissolved, the result of their experiments may be summed up as follows:—

(1) A 12-inch B.L. of 43 tons had been made, and after passing a very satisfactory proof had also fired a few rounds at Shoeburyness.

(2) A 10·4-inch B.L. gun, which had passed proof in June, 1880, had fired more than 50 rounds, from which valuable information had been collected.

(3) A 9·2-inch B.L. gun of 18 tons was under construction.

(4) 6-inch B.L. guns had been designed in the Royal Gun Factory, superior in power to the guns which had been purchased from Elswick.

(5) Two 25-pr. guns had been completed, and were awaiting a programme of trials.

Principles of construction.

All the foregoing guns had been designed in the Royal Gun Factory, and embodied the following principles:—(*a*) the interrupted screw system for closing the breech, being a modification of that used by the French; and (*b*) maintenance of the latest method of construction as applied to R.M.L. guns, viz.: a steel barrel reinforced by wrought-iron coils, with the trunnion piece welded to the breech coil.

Ordnance Committee, 1881.

When the Ordnance Committee was appointed in April, 1881, their attention was specially directed to the new B.L. guns.

6-inch Mark II.

About this same time an order was given for the manufacture of a considerable number of 6-inch guns on the R.G.F. plan; some were to be made by the Elswick Ordnance Company, and the rest by the Royal Gun Factory. These constituted the 6-inch Mark II.

Enlargement of chamber in

In May the Committee recommended the adoption of a suggestion made by Colonel Maitland, Superintendent of the R.G.F., that the breech-

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openings of the 12-inch, 10·4-inch, and 9·2-inch experimental guns should be enlarged. The object of this was to admit cartridges of slow-burning powder made up to the full diameter of the chamber.

experimental guns. New construction for slow-burning powder, 9·2-inch, M.L.

With the introduction of prismatic powder and the probable use of slow-burning powder in future, a new design was also put forward by the Superintendent R.G.F. for the 9·2-inch guns of 18 tons. This differed from the experimental gun in the following points:—

(1) In having steel coils in front of the trunnions instead of coils of wrought-iron;
(2) In being 22 inches longer;
(3) In having a short chamber of much larger diameter than bore;
(4) In the use of a thicker steel core; and
(5) In the barrel being left unsupported by exterior rings for a length of 122 inches from the muzzle.

Steel guns, 8-inch.

At the same time he urged that steel should enter m largely into the designs for all heavy guns, than it did in the experimental pieces then under trial. The Committee supported this view, and before the close of 1881 some 8-inch guns entirely of steel were commenced: the construction took the form of a barrel supported by coils, the trunnion piece being screwed to the breech coil as steel portions could not be welded together like iron.

12-inch Marks I & II.

Early in the next year (1882) it was decided to make the 12-inch guns on a design very similar to that which had been approved for the 9·2-inch. For S.S., however, the trunnions were supplanted by ribs, to be bedded in the carriage of a new description put forward by the Elswick Ordnance Company. These are the 12-inch Marks I and II, in which the construction and dimensions are exactly the same; they differed only in the fact of the Mark II being trunnionless guns.

4-inch M. II.

A 4-inch Mark II was also designed in the spring of this year, in which the steel barrel was reinforced by steel hoops, and as the Committee saw no objection to manufacture for general supply being carried on simultaneously with that of an experimental piece, a number were ordered at once.

6-inch M. III.

By this time many 6-inch Mark II had been made, and the trials at Shoeburyness had been most satisfactory. But certain guns of E.O.C. manufacture showed signs of weakness at proof, and one or two failures occurred in guns manufactured at Woolwich from deficiency of longitudinal strength; so special tests were applied to several guns, some of which had partially failed. These guns stood their test, but it was thought desirable to lower the charge, and a fresh design was put forward for a Mark III 6-inch gun of stronger construction. This consisted of a steel tube reinforced by steel hoops, but before any guns of this pattern were much advanced, another change was approved which superseded this earliest design.

Report of the Ordnance Committee.

In May, 1882, Sir William Armstrong & Co. made sundry objections to the designs of 12-inch of 43 tons, which they were about to manufacture by contract. This led to a thorough investigation before the Ordnance Committee of the whole subject of construction of guns. Amongst those who gave evidence were Colonel Maitland, R.A., Sir William Armstrong, C.B., Captain A. Noble, C.B., Mr. Vavasseur, C.E., Dr. Siemens, F.R.S., and many others. The report of the Committee, as regards the material for guns, recorded the following opinion:—

(1) That the superiority of steel over wrought-iron was so marked that the latter should be entirely abandoned; and

CHAP. I.

(2) That coiled steel, though superior to coiled iron, was inferior to cast steel forged out into hoops.

They therefore recommended that ordnance should be composed entirely of steel, and that cast steel should be used for the exterior rings, rolled, hammered, or mandrilled into forged hoops. A specification was drawn out by the Committee, but these tests have had to be modified several times.

Coiled iron given up in favour of steel.

On approval of this change in construction by the D. of A. in the autumn of 1882 new designs were supplied by the Superintendent R.G.F. for all natures of guns then in hand, but on account of the forward condition of certain guns already commenced, it was found impossible to adopt the new type of construction at once.

Breech-piece for longitudinal strength.

In 1883 a further change was proposed to relieve the breech end of the barrel from the intensity of strain arising from a combination of transverse and longitudinal stress which naturally has a maximum value in the region of the front threads of the screw. The thickness of the tube had been less at this point than at any other part of the breech. It was suggested at first that the barrel should be furnished with a "plus" thread, by which contrivance the thickness of steel at this particular part would at any rate not be reduced. Afterwards a breech-piece was adopted to receive the breech-screw instead of allowing it to gear into the barrel. This proposition met with decided approval, and it was at once applied to all the natures of guns that were then under construction. In the smaller natures, having only one layer of metal over the barrel which is commonly known as the jacket, the breech-screw gears into this piece in the manner shown by a sketch in the chapter on Gun Construction in the first part of this book.

Varieties of construction.

Bayonet-joint.

In the same year a further improvement was made in the Royal Gun Factory to gain longitudinal strength and distribute the strain more evenly through the material. This consisted in locking the portions of the gun firmly together by means of a bayonet-joint during the operation of shrinking, so that end-strength is vastly increased and forward movement of the barrel is rendered impossible. The jacket or tube which has thus been turned round in its seat, is keyed in position by wedges driven into the intervals through which the projections have passed; one wedge would be sufficient no doubt for this purpose, but by driving in wedges all round and by giving them a uniform slope, continuity of metal is preserved to meet any stress at that part which might be felt in a transverse direction.

Varieties of construction.

There are consequently amongst B.L. guns of new type a great variety of constructions which may be briefly summed up as follows:—

(1) The E.O.C. first construction, represented by the 6-inch 81 cwt. gun (80-pr.), viz., a steel tube with numerous wrought-iron coils.

(2) The R.G.F. first construction, to be met with in the 4-inch Mark I, viz., a steel tube with a wrought-iron jacket and B-coil.

(3) The R.G.F. second construction, as seen in the 9·2-inch and 12-inch Marks I and II, viz., a steel tube with steel coils, and a wrought-iron breech-piece and jacket.

(4) The first R.G.F. steel construction, which was applied only to 8-inch Marks I and II, and to two experimental field guns, viz., a steel tube reinforced with steel coils, the trunnion-piece being screwed on to the breech-coil.

(5) The second R.G.F. steel construction, consisting of a steel tube with rings of cast steel, forged and mandrilled out into hoops; this will be found in the 4-inch Mark II, 5-inch Mark I, and 8-inch Mark III.

CHAP. I.

(6) The third R.G.F. steel construction, in which the breech-screw gears into the breech-piece, so that this portion takes all (or nearly all) the longitudinal stress.

(7) The E.O.C. construction, as applied to the guns of 110 tons now being made, viz., a barrel and a breech-piece with a great number of small exterior hoops extending from muzzle to breech ; and

(8) The latest R.G.F. system, which embodies a breech-piece to take the breech-screw, and a few exterior tubes of great length, shrunk on with bayonet-joints, so that all parts are firmly united together in a manner which enables them to share the stress in any direction. A liner is fitted into the breech end of the A-tube, to facilitate repair when the bore at that part becomes much eroded, and an *a*-tube is shrunk into the muzzle end to strengthen that portion.

Wire guns.

To these we shall soon have to add another system in which the chief feature is wire. Experiments in the use of steel wire, as regards tension, form, size, and method of winding, have been conducted at Elswick and Woolwich for several years; the initial compression of an inner tube obtained by this means may be exceedingly great, and the strength of a cylinder therefore proportionately high to meet a great stress from within. The chief difficulty has been hitherto to provide longitudinal strength with any system of wire construction; but this difficulty is now overcome. Wire guns have been made with success, and some are in course of manufacture, but these must be considered only experimental pieces as yet.

Table for comparison of M.L. and B.L. guns.

A table is appended to show the power of some new B.L. guns for comparison with that of the M.L. ordnance which they are intended respectively to supersede (see next page).

Before describing in detail these B.L. guns of new type, it will be desirable to devote a chapter or two to the R.B.L. guns of earlier design, which are still retained in the service.

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TABLE XXVII.

TABLE showing Ballistics of M.L. and B.L. Guns approximately of the same weight.

Gun.	Weight.	Charge. Powder.	Charge. Density.	Projectile.	Muzzle. Velocity.	Muzzle. Energy.	Perforation at 1000 yards.	Remarks.
		lb.		lb.	f.s.	f.t.	inches.	
9-pr. M.L.	8 cwt.	1¾ R.L.G.	..	9	1830	118	2·3	
12-pr. B.L.	7 „	4 P.	28·9 / ·959	12½	1705	252	3·7	
16-pr. M.L.	12 „	3 R.L.G.	..	16	1355	203	3·0	
22-pr. B.L. (Expl.) ..	12 „	7½ P.	29·8 / ·930	22	1735	458	5·2	
40-pr. M.L.	35 „	7 R.L.G.	..	40	1380	528	4·0	
5-inch B.L.	38 „	16 P.	32·0 / ·866	50	1780	1008	6·9	
7-inch M.L.	90 „	22 P.	..	115	1325	1400	6·6	
6-inch B.L.	86 „	34 P.[2]	40·9 / ·678	100	1660	1911	8·8	
9-inch M.L. (M. V)..	12 tons	50 P.	..	258	1420	3607	10·2	
8-inch B.L. (M. VI)..	14 „	100 Prism[1].	30·5 / ·909	210	2030	5973	14·1	
12·5-inch M.L. (M. II)	38 „	210 Prism.	28·6 / ·970	818	1546	13554	17·1	
12-inch B.L. (M. IV)	45 „	295 Prism[1], brown.	33·1 / ·838	714	1892	17723	20·4	
17·72-inch M.L. ..	100 „	450 Prism.	37·7 / ·735	2000	1548	33233	22·8	E.O.C. guns.
16·25-inch B.L. ..	111 „	200 C.	32·5* / ·854	1800	2020*	50924*	30·6*	* Estimated.

PART III.

CHAPTER II.

R.B.L. GUNS: MANUFACTURE, FITTINGS, AND STORES.

The class of ordnance described in this chapter has been successively designated the "Armstrong," the "vent-piece," and the "B.L. screw" guns. The name of Armstrong was naturally given to them in the first instance, from the fact of their having been originally designed by that eminent engineer and inventor. When muzzle-loading guns were adopted they were commonly spoken of as the "breech-loaders," there being no other kind of breech-loading guns in the service; and again when other B.L. guns were brought in, they were called for a time "vent-piece" guns, from that distinctive feature in their breech-closing arrangement. Owing to the conversion, however, of some into "side-closing" guns, the vent-piece has been changed to a solid stopper or block, and then the term "vent-piece" had to be given up. Now they are called "R.B.L. guns," in contradistinction to the "B.L. guns" of later date, which are closed with an interrupted screw, and in all reports and returns it is necessary to adhere to this designation.

There are three main points which will have to be separately considered, in every type of breech-loading gun, viz.: (1) construction, (2) method of closing the breech, and (3) the system of obturation, or means of thoroughly preventing the escape of gas.

Introduction in 1859.

All R.B.L. guns were made on Sir W. Armstrong's original system of construction, which, with his breech-closing arrangement, was adopted in 1859: and although the manufacture of this class of gun was discontinued in 1864, there are so many still in the service and held in reserve, that it will be necessary to explain fully their mechanism, fittings, and stores. The men who are liable to use any of these

CHAP. II.

guns should also be instructed in the repairs which may have to be carried out to maintain their efficiency on service.

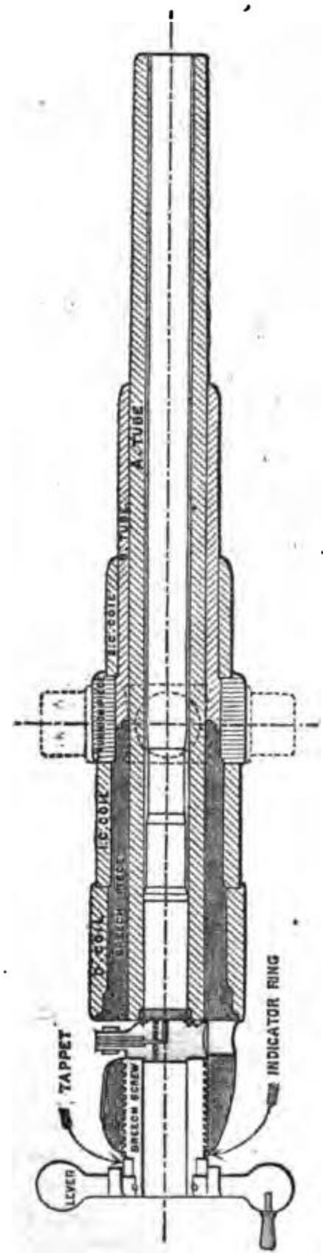
Construction.

The original construction consists, as already stated, of an inner barrel of coiled iron,* a solid forged breech-piece, a forged trunnion ring, and one or more exterior coils according to the size of the gun: for instance, the 6-pr. has only one, and the 7-inch of 82 cwt. has six.

As an example of manufacture we may take the 40-pr. of 35 cwt., the construction of which may be seen in the sectional drawing here given.

40-PR. 35 CWT. MARK I.

Scale, 1/12.



* The 3-pr. R.B.L. gun submitted by Sir W. Armstrong in 1855 had a stcel barrel, but that material was abandoned owing to the difficulty of getting it of suitable quality at that time, especially for guns of large size.

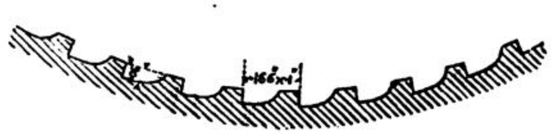
CHAP. II.

The barrel or A-tube was made of five welded coils united end for end with a spigot and faucet joint after being previously put together by shrinking: the exact number of coils would of course vary with the length of the barrel for different natures of guns. Coiled barrels were afterwards abandoned in favour of solid forgings of iron, which were bored out into tubes. These were adopted on account of the difficulty experienced at one time in making coiled barrels free from defects as shown by the coil marks and imperfect welds after firing. But forged barrels again were soon given up, for although free from defects in the bore they proved to be deficient in strength; for the fibre in the iron ran lengthways, and the barrel contributed little to the circumferential strength of the gun, in which direction alone its strength is required, for the breech-piece takes all the longitudinal stress. Steel barrels were then tried and subsequently adopted for all natures of ordnance. Any R.B.L. guns which have since required a new tube have received a barrel of steel.

The breech-piece was forged in a solid block and bored out very nearly to the diameter of the A-tube; the breech-screw gears into this portion, which therefore is expected to absorb nearly all the longitudinal thrust. The trunnion ring also was forged from a solid mass of wrought iron in the manner already described, which was afterwards retained in the manufacture of R.M.L. guns. The requisite number of exterior coils were separately prepared, and the gun was built up by shrinking these parts successively over the barrel. In this construction the trunnion ring was not welded to any outer coil as in the jackets afterwards made, but it was shrunk on by itself, trusting only to the grip of shrinkage for the necessary end-strength in the gun.

After the gun was built up it was brought to the necessary dimensions by turning and boring. It was then rifled on the Armstrong polygroove system with uniform twist. The number of grooves would depend on the size of the bore, but they were all of the same character, though not exactly of the same size; the form is shown in the accompanying sketch, the driving side being radial to the bore. The

SECTION OF RIFLING (full size).



lands were left narrow so to remove as little as possible of the lead with which the projeciles were coated to take the grooves of the rifling.

Breech-closing arrangement.

Breech-closing.

Two methods at first were employed for closing the breech, viz.: (1) by means of a stopper dropped into a slot, which was held firmly in position by a powerful screw; and (2) by means of a stopper and wedge worked on opposite sides through the breech. The latter system has been pronounced obsolete;* we have therefore to explain only the stopper and screw.

* A few 7-inch wedge guns, and a considerable number of 40 and 64-prs. were made with this system of closing the breech; some were issued to the Navy, but they were soon withdrawn from the service and the whole class placed in reserve. In 1883 they were pronounced "obsolete," and it was decided that they should all be broken up.

Preparation of the gun for Breech Fittings.

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Vent slot.

After being built up and rifled the gun was prepared for the breech mechanism by having a slot cut in the upper part of the breech for insertion of the stopper, and underneath this a circular hole was drilled through the lower side of the gun, which was called the "water escape" or "drip hole."

Chambering.

The gun was then chambered, *i.e.*, the powder chamber and shot chamber were bored out to their respective dimensions. The diameter of the former was rather the greater, removing all the lands of the rifling: the latter, which is slightly conical, does not remove the whole of the lands, and this acts as a stop for the shell in loading.

Grip.

Immediately in front of the shot chamber there is a "grip" in the bore, which is the smallest diameter in its whole length: this is the real calibre of the piece, and the grip is given to the gun that the coating of lead on the projectile (as the latter begins to move) shall be thoroughly compressed into the grooves. From the grip to the muzzle the bore is lapped out to reduce friction until at the muzzle it is about ·005 of an inch larger than the actual calibre.

Screw threads.

The breech end of the A-tube was next bored out and threaded to receive a breech-bush, and the part of the breech-piece in rear of the slot was prepared with a female thread for the breech-screw.

Breech Fittings.

Breech fittings.

The breech fittings for R.B.L. guns are as follows:—

Vent-piece.
Breech-screw.
Tappet ring.
Lever and keep-pins.
Indicator ring.

The Vent-piece.

Vent-piece.

The vent-piece is the block of iron or steel which closes the end of the bore after loading. It received this name because the vent was placed in it in preference to boring a hole in the gun: the operation of reventing was thus also abolished, for a new vent-piece could always be taken into use without any delay.

The vent channel passes down through the neck to the centre of the block, and thence horizontally to the face of the piece, so that the cartridge is axially ignited. The axial position, however, was not intended to confer any advantage as regards pressure or ballistic effects; it was so placed for maximum strength in the block.

Material.

The material has been frequently changed; wrought iron first, then steel, then Swedish iron, then steel toughened in oil, and lastly Marshall's refined iron, have been employed. The material of which a vent-piece is made is always stamped on the back.*

Saddle.

The vent-pieces of all except the 40-pr. and 7-inch guns are lifted away from the gun after firing each round, but with these two (the heaviest) natures they have to be placed on a saddle or rest, just in rear of the slot on the top of the breech of the gun.

Parts of a vent-piece.

A vent-piece consists of a body, vent-bush, copper ring (except for the 7-inch), a cross-head, and shackles.

* In 1881 it was decided that all steel vent-pieces should be considered obsolete, in consequence of several splitting on service: they should accordingly be returned into store.

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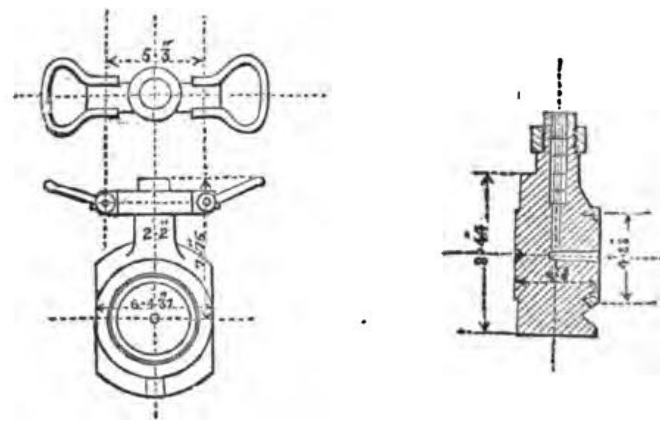
There is a "foot" on the 7-inch and 40-pr. vent-piece to enable a man to hold it in a vertical position, and also to prevent the face from being injured when the vent-piece is dropped into the slot.

SERVICE VENT-PIECE.



The vent channel is bushed at the upper end only. The bush formerly consisted of three or four plain cylinders of copper about an inch long, with one piece screwed in at the top: now only one long plain cylinder is used instead of the short pieces. The bottom is not bushed, because the block would be too much weakened thereby.

The copper ring is attached to the face of the vent-piece by means of an annular undercut groove, into which the ring is sprung or driven by force. The ring is made of pure copper and it has a dovetail corresponding to the form of the seat in the vent-piece. To put it on, the vent-piece is placed in a screw press and the ring is then force into the groove. On service the breech-screw may be used for this purpose.

Cross-head and shackles. The cross-head and shackles are not put on till after proof. The cross-head is made from a block of scrap iron, and is so shaped that its projections rest on the slot when the vent-piece is in the proper position for being screwed up. Great pains were taken to get this correct, to prevent the possibility of the vent-piece ever going wrong.

O.P. vent-pieces. The material, date of manufacture, pattern, and number are marked on the block, and the latest pattern available should always be used: O.P. vent-pieces without a projection at the back should on no account be employed.

Breech-Screw.

Breech-screw. The breech-screw is made of steel toughened in oil for all guns of this class except the 7-inch, which has an iron screw faced with 6 inches of steel, for an iron face would be liable to get dented and "set-up" under the pressure of the screw and reaction of the gas on firing. The thread is of the "V-bevelled" type, so called from the shape of its section, which is less liable to get clogged by dust and grit and more easily worked than the square thread. A few of the earliest guns may be found in which the square thread was employed; the breech-screws in such a case are not interchangeable with those of the service pattern.

The 7-inch gun and its breech-screw have a double thread; this gives double the amount of travel in working without reducing the bearing surface of the screw.

All breech-screws are marked with the nature of gun, but not for any

particular piece, although the register number should at any rate at first correspond with the number of the gun.

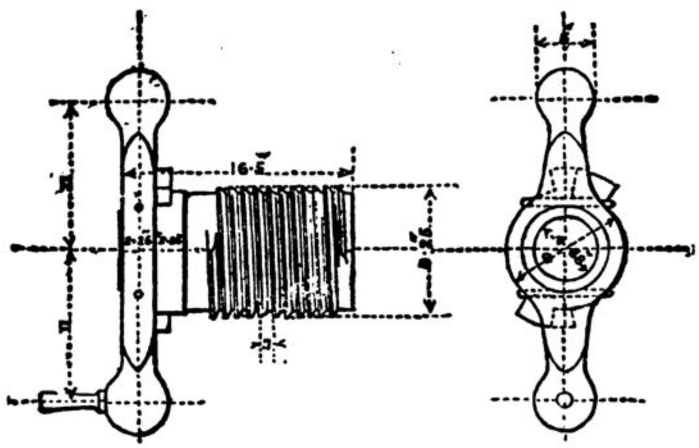
The screws for the 40-prs. of 32 and 35 cwt. are not interchangeable, having a different pitch and form of thread.

The bore of the screw.

The hollow or bore of the screw is slightly less in diameter than that of the chamber in the gun, to prevent the breech bush from getting damaged by the projectile when loading.

40-PR. BREECH-SCREW, TAPPET RING, LEVERS, AND KEEP-PINS.

Scale, ¾ inch = 1 foot.



Tappet Ring.

Tappet ring.

The tappet ring is octagonal in the interior, and fits on a similar octagon on the rear part of the breech-screw; hence it acts as a wrench to the latter, the power being communicated from the arm of the lever by means of the tappets, which come into contact with projections on the tappet ring.

Lever and Keep-Pins.

Lever and keep-pins.

The lever fits on a circular part of the breech-screw behind the tappet ring; it is free to revolve round the screw, but is prevented from coming off by two keep-pins, which work in a cannelure. The lever is fitted with weight balls to give dynamic power in screwing up and releasing the screw. The levers are all of wrought iron, the handles being screwed into the weight balls. The small natures of R.B.L. guns have one handle and weight ball; 40-prs. have two balls but only one handle; 7-inch guns have two handles and balls. The levers all have a play of ·02 inch round the breech-screw, and as there is no particular strain on them they are not easily damaged; they are interchangeable for guns of the same nature. A handle can be easily renewed if it should happen to get broken off.

Indicator Ring.

Indicator ring.

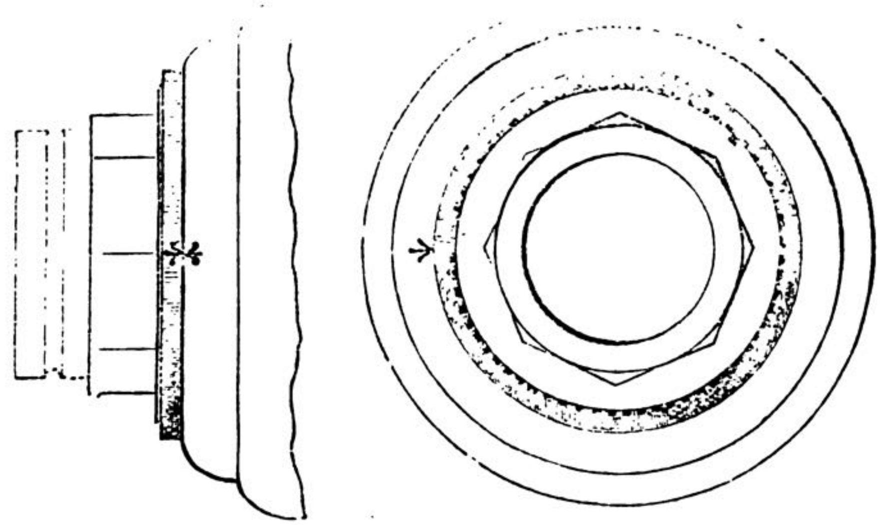
The indicator ring is a thin, narrow ring of wrought iron, fitted on the breech-screw in front of the tappet ring; on the internal circumference there are a number of grooves or feather-ways, any one of which will fit a "feather" on the breech-screw; it should be so adjusted that when the vent-piece is properly screwed up the brass index or arrow on the

CHAP. II.

indicator ring and that on the top of the breech-piece should be opposite one another; then it can be seen at a glance when in action whether the vent-piece is properly screwed up, or in the dark this could be ascertained by the touch. As the copper ring and breech-screw are faced on service and the metal thereby cut away, the position of the index may have to be altered; this is done by shifting the ring on the breech-screw, so that the feather takes a different groove.

RINGS, INDICATOR (FOR 7-INCH R.B.L. GUN).

The shaded portions show the indicator ring. Tappet ring removed.



Guns having indicator rings.

The 7-inch and 40-prs. are the only guns with which an indicator ring is considered necessary; but some 40-prs. of 32 cwt. do not use them, not having sufficient length of breech-screw.

Obturation.

Obturation.

To make the joint gas-tight between the stopper and the end of the bore two copper rings are employed, which are faced convex and concave with a corresponding angle, to ensure a close fit. One ring

SYSTEM OF OBTURATION.

is affixed to the face of the vent-piece and the other (commonly called the breech-bush) is screwed into the bore of the gun. Either ring can be easily refaced with tools which are supplied for the purpose, and when worn out they can be replaced by others. They are made of copper in all except the 7-inch guns, which are now bushed with iron, as copper rings were found to work loose.

With 40-pr. and 7-inch guns a tin cup is also used, which assists the obturation by preventing the gas from acting with full force on the joint.

Copper was found to be unsuitable for 7-inch guns, from the liability of this metal to damage and the want of stiffness in rings of so large a diameter, so the vent-piece itself is faced to the angle required, and the iron bushes are supplied for the bore. The iron bushes first used were 2 inches long and ½ inch thick; but as these occasionally shifted from want of screw bearing a second pattern, which was 3 inches long and ¾ of an inch thick, was adopted. This could be inserted in guns already bushed with the earlier pattern, and when this was done such guns were marked DB on the right trunnion.*

Proof.

Proof. A R.B.L. gun was proved without its breech-closing gear (spare parts being used) by firing six rounds with a charge half as heavy again as that appointed for service and with a shot equal in weight to the service projectile. The bore was carefully examined by means of gutta-percha impressions, and by gauging both before and after the firing, as described for muzzle-loading guns.

Vent-pieces and breech-screws underwent two service rounds independently.

After Proof.

The guns having passed proof were marked, lined, sighted, &c., prior to issue.

Marks on the gun. The weight of the gun, Royal Monogram, and broad arrow were stamped in front of the slot, and the mark,† name of factory, date of proof, and register number on the left trunnion.

Sighting. Vertical and horizontal lines were engraved on the breech and muzzle, for the purpose of enabling the sighting plates to be adjusted. These are also of practical use in the repair of this class of gun. Horizontal lines were marked on the right side of the breech, right trunnion, and right side of the muzzle, except on field guns; and vertical lines also intersecting those on the breech and the trunnion.

Sights.

Sights. All R.B.L. guns are sighted on both sides, having two tangent‡ and two fore-sights.

Socket ring. As the amount of metal at the breech end of the gun is small in all

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* Prior to the introduction af this pattern bush, all 7-inch guns had been bushed either with copper or the thick iron bush. It is advisable to re-bush with iron any guns still retaining the copper: and guns which are not prepared for the new pattern bush must be furnished with a bush of old pattern. Guns marked DB would of course be re-bushed with a 3-inch bush, or if necessary with both.

† Some B.L. screw guns may be found without any numeral stamped on the trunnion, because the order for marking in this manner was not in existence when the first guns of this nature were issued.

‡ For the different patterns of these sights see Table XXIX, at the end of this chapter.

CHAP. II.

natures except the 7-inch, the tangent sights are set in a wrought-iron ring, which is screwed on to the breech and secured to the gun with the sockets inclined at an angle of 2° 16′ to the left, this being the angle of correction for drift.

For the 7-inch holes are drilled in the breech of the gun itself at an angle of 2° 16′, and sockets are adjusted in them which are similar to those described for R.M.L. guns.

The fore-sight holes are drilled perpendicularly, and in guns using screw sights these holes are prepared with a screw thread.

Tangent sights. Generally speaking, the tangent sights consist of steel rectangular bars with barrel-shaped heads, or in the latter pattern (introduced in 1867) with a plain head and sliding leaf for deflection; but for the 12-pr. guns, 7-inch of 72 cwt., and a few 7-inch of 82 cwt. also, the bar is hexagonal in shape and made of gun-metal. The reason of this difference lies in the fact that these natures were the first introduced, and it was then thought that hexagonal bars would suit best, with graduations on all the six sides. Afterwards, when rectangular steel bars were preferred, it was not thought worth while to alter the few 7-inch guns so prepared, while on the other hand the trouble of altering the 12-pr. guns then scattered all over the world would have been very considerable.

Elevating nut. L.S. sights have a slow-motion "elevating nut," the circumference of which is graduated from 1′ to 10′, so that minutes of elevation can be accurately obtained. This was considered unnecessary for sea service sights, which therefore have no slow-motion nuts; in all other respects the sights for land and sea service are just the same.

O.P. sights. Many sights of old pattern, and still earlier hexagonal sights of E.O.C. manufacture, may possibly be met with in forts, but these, if corrected to the latest graduation and brought up to date, are not to be considered obsolete.

In barrel-headed sights the leaf is traversed by means of a mill-headed screw at each end of the barrel. The screw has a pitch that makes one complete turn in moving the leaf through a distance of 10 minutes; the circumference is accordingly divided into ten equal parts, so any exact number of minutes can be accurately given. There are arrows on the head to show the direction in which the screw must be turned to give deflection to the right or left. The deflection scale is graduated for 30 minutes either way.

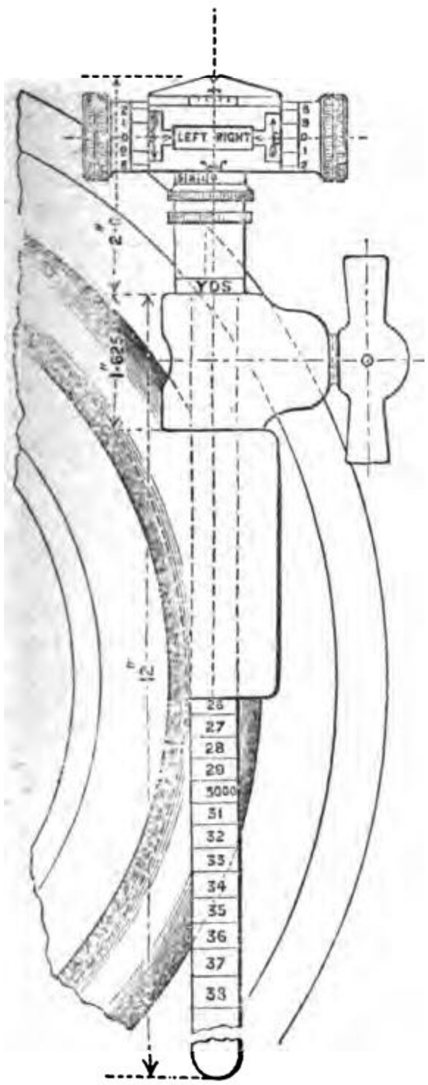
Sliding-leaf sights. In the sliding leaf pattern the leaf is traversed by hand and clamped in the required position by a mill-headed screw on the back or muzzle side of the sight: this, though not quite so accurate as the old pattern, has the advantage of lightness, and is not so liable to become stiff in working.

Graduation of tangent bars. The steel tangent bars are graduated on one of the narrow sides in degrees, and on the other in yards. Those for the 7-inch guns of 82 cwt. have also a graduation on one of the flat sides (right) for tenths of fuze corresponding to range. Each degree is divided into six divisions of 10 minutes each.

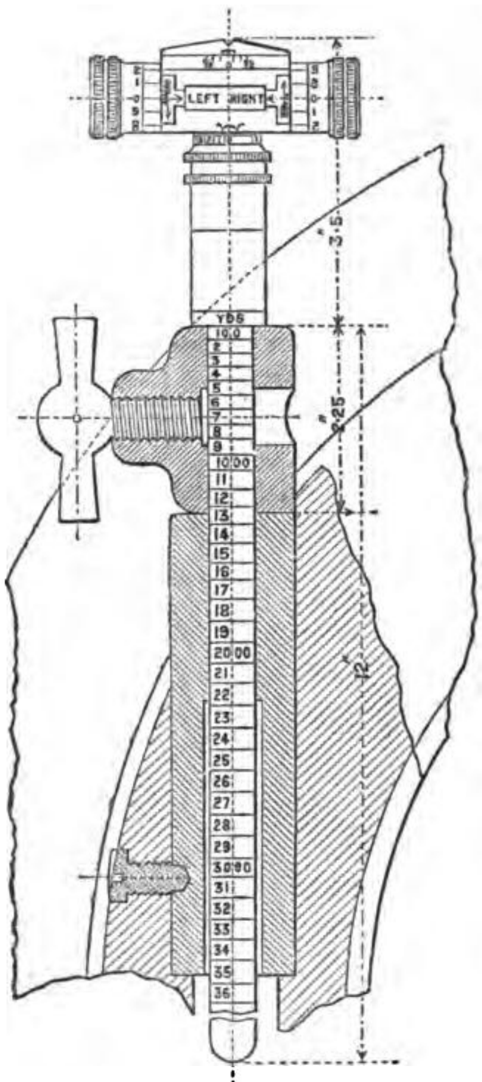
BARREL-HEADED SIGHTS, WITH MOVEABLE CLAMP.

Scale, $\frac{3}{8}$ inch = 1 foot.

R.B.L., 40-pr., 35 and 32 cwt.
(with socket-ring).



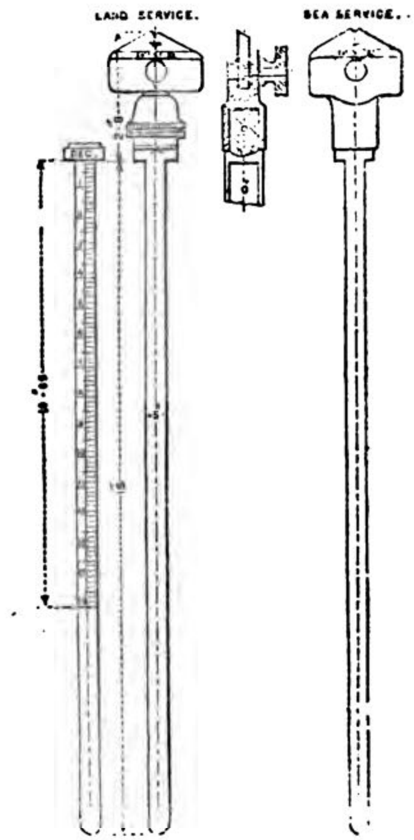
R.B.L. 7-inch 82 cwt. (with
gun-metal socket).



CHAP. II.

SLIDING-LEAF SIGHTS.

Scale, 2½ inches = 1 foot.

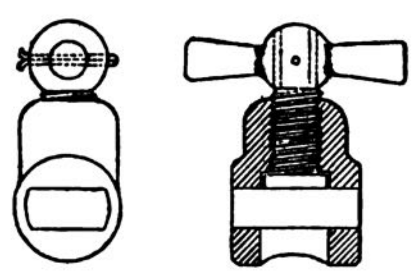


Copper set screws.

In the 20-pr. and smaller natures of R.B.L. guns the tangent sight is clamped at elevation by means of a copper-set screw, secured by a chain to the piece. In other natures* the sight is fixed by a

Moveable clamp.

MOVEABLE CLAMP.



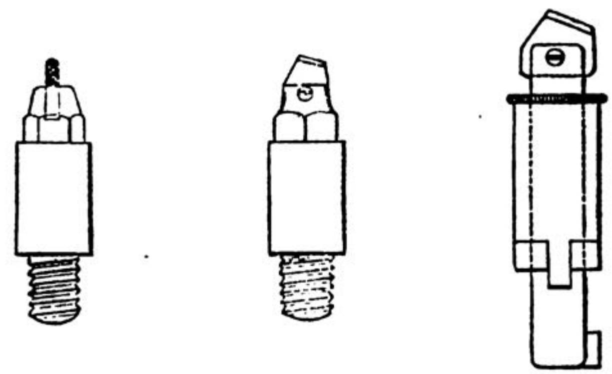
"clamp tangent sight" which permits of the sight being removed from the socket to be taken to the light for adjustment during the operation of loading; this is found to be a useful arrangement between decks or in casemates, and generally too in the field.

Fore-sights.

There are two patterns of fore-sights, viz.: the *screw* and the *drop* pattern. The former is used with field guns that they may not be

* The 7-inch of 72 cwt. also has its sights clamped by a set screw.

shaken out when moving over rough ground. The latter is supplied to the 20-pr. and all higher natures, except the 7-inch of 72 cwt., with which a large screw fore-sight is used, altogether of exceptional pattern; this may also be met with on a few 7-inch of 82 cwt.



The advantage of the drop pattern is this, that the sight can be easily removed during transport, and placed in position for use without trouble; spare sights, too, can be carried which are ready to be placed in the gun without any adjustment;* the service sights can also be kept safely in store when not required for use.

Drop fore-sights are issued complete, with the leaf finished; but screw sights must be issued with rough leaves; hence it is chiefly with field guns that the process of repair and adjustment may have to be performed while on service.

Both tangent and fore-sights are marked for the nature of gun to which they belong, and all tangent sights (both L.S. and S.S.) are interchangeable for the same *nature* of piece except those for the L.S. and S.S. 20-pr. guns, which are sighted to a different radius.

For S.S. all R.B.L. guns, from the 7-inch to the 20-pr. inclusive, are supplied with side scales: these are flat bars of wood graduated to 12° elevation and to 6° for depression. In the case of the 20-pr. 13 cwt. gun, when used on the deck of an ironclad ship, the wood side scale has a moveable pointer similar to those which are supplied for R.M.L. guns, and this is graduated for 20° of depression. Wood side scales.

Stores.

The stores for R.B.L. guns which are supplied by the Royal Gun Factory are enumerated in a table at the end of next chapter; but a few remarks will be made here about them.

Bearers, shot.—These shot bearers are made of wrought iron, with three handles covered with leather, and are so constructed that the projectile cannot drop out after the weight is once taken. They are known as "Alderson's pattern." Two are issued for each 7-inch gun. § 919.

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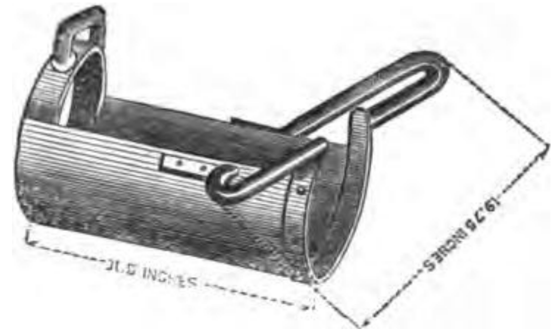
* Screw sights are nominally interchangeable for guns of the same kind, but on account of the difficulty in preparing the thread of the screw with the accuracy required in this case, some small error might occur with any change of position.

CHAP. II.

BEARERS, SHOT.



§ 842. *Bits, vent (Armstrong).*—The Armstrong vent bit is of steel, with a cross-handle of wood, similar in shape to a gimlet. It is used to clear the vent channel if the copper bush should become choked or

BITS, VENT (ARMSTRONG).

Scale, ¼.

burred. There is but one pattern. They are issued in the proportion of one bit to four guns, except for field service when there is one for every division, and for sea service when they are issued according to the requirements of the ship.

§ 399. *Bushes, breech, iron, thick, 7-inch.*—Two inches long, ½ inch thick, for screwing into the breech end of the A-tube of 7-inch guns.

§ 467. *Bushes, breech, iron, thin, 7-inch.*—A later pattern 3 inches long, and ¼ inch thick; this can be screwed into a gun already bushed with one of the earlier pattern. Spare, 1 per gun.

§§ 526, 530, 1145. *Bushes, breech, copper.*—To be screwed into the breech end of the A-tube of 40-pr. and all smaller guns; they should project 0·03 of an inch, to enable them to be refaced on service. Spare,* 2 per gun.

§ 1232. *Bushes, copper, vent-piece.*—For the vent channel. Spare,* 1 for every

* These copper articles should be carried in some place where they would not be liable to be injured or knocked out of shape.

two guns for 7-inch, and 40-pr. when mounted in forts: one for each gun for field service. CHAP. II.

Clamps, tangent sights.—Similar to those used for R.M.L. guns. § 1144, 1357.

Collars, leather, for breech-screws.—This collar is supplied for 12-pr. guns, and is made to fit on the breech-screw close to the breech of the gun. When a thicker vent-piece was adopted for strength, and the slot in the gun widened accordingly, some threads of the breech-screw were exposed, and this collar was introduced to protect that part and keep off the dirt. It can be pared if necessary as the copper is cut away in facing the ring or the bush. § 845.

Crutches, iron.—The vent-pieces for all except 7-inch guns do not afford room for a friction tube pin for sea service, so they are fitted with a crutch, attached round the mouth of the vent by two § 27, 688.

CRUTCHES, IRON.

Scale, ½.

screws. A slot is cut in the vertical part of the crutch, through which the friction bar of the tube should be passed; the head is supported in this manner when pulling the lanyard, and the risk of its being broken off is reduced.

For field marine service the crutch has two slots, so as to enable the gun to be fired from the left side when on land, the right side being commonly used on board ship.

Extractors, tin cup.—The tin cup extractor for land service is simply an iron hook with a wooden cross-handle. One is issued to each gun using tin cups. See drawing on the next page. § 733.

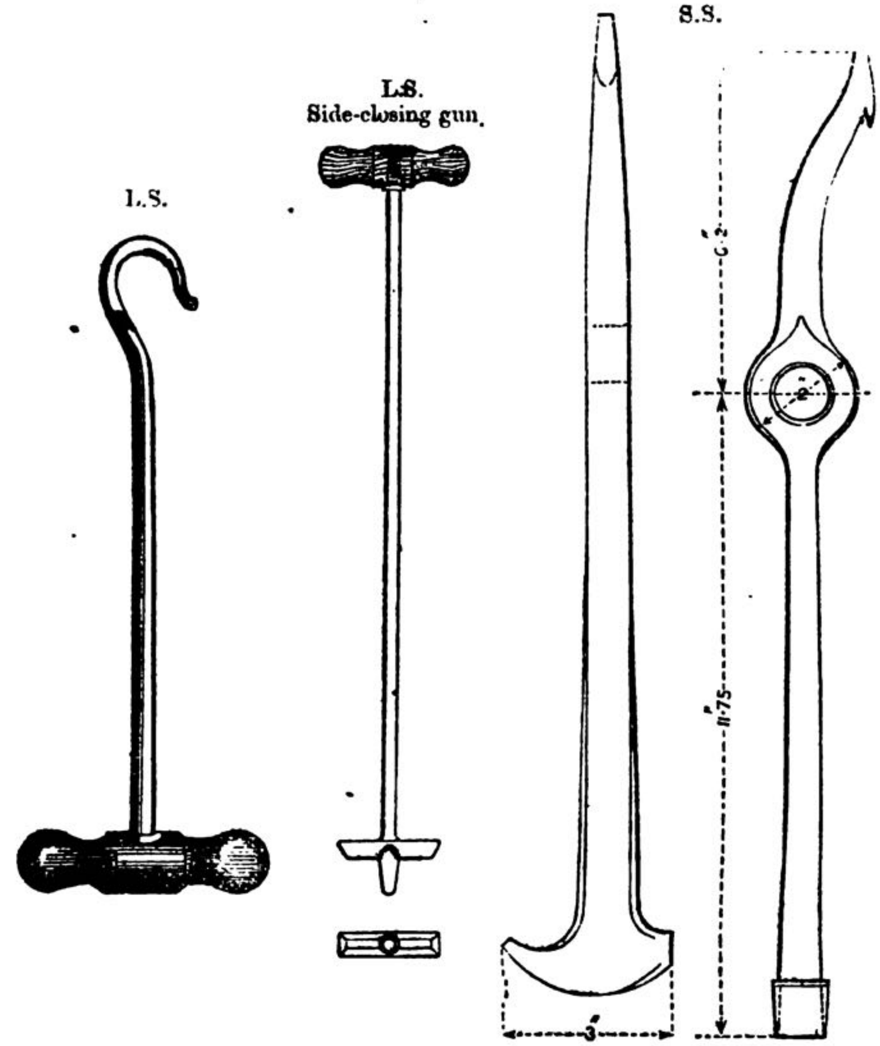
For S.S. it is an iron lever with a barbed hook which is pivoted at the end to pass through and extract the tin cups; at the other end it has a curved hammer which can be used as a "lever lifting joint." § 1259.

For the 40-pr. side-closing gun a new pattern extractor has been recently made, which is longer in the rod, and the hook has been exchanged for a T point.

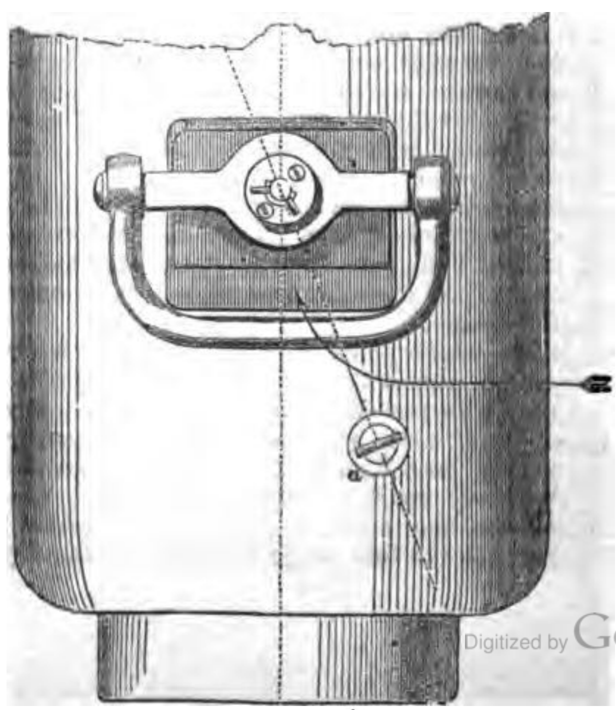
Eyes, elevating (with bolt, washer, and keep-pin).—The elevating eyes are of iron, and they are screwed underneath the breech of L.S. guns. For the 20, 12, and 9-pr. guns they are double-headed, but for the 6-pr. solid; the heads of the elevating screws will therefore respectively be single or double-headed. § 173, 69. 711, 998, 102.

Lanyard guide.—Guide plates are of steel, and one is screwed on to the breech of each S.S. gun at the right rear of the slot to guide the lanyard (which should be passed through it), and give a direct pull on the tube. It has a crosshead to which a loop on the lanyard can be attached when the gun has been loaded, to prevent it from being fired accidentally. The Navy use it because they fire their guns just as the object crosses the line, and this guide plate enables the gunner to have a direct pull on the tube while looking over the sights. § 476, 688.

EXTRACTORS, TIN CUP.



Scale, ½.



Angle 20°.

Instruments, facing.—The use of these instruments is described in Part IV, and a table is there given of the tools which are comprised in a set. The sets are issued for 7-inch and 40-prs. in the proportion of one per district or battery and one in reserve; for other guns one set per battery only. CHAP. II. § 515, 516, 574, 575, 745, 1073.

Instruments, taking impressions of the bore.—These are supplied in two sizes:—No. 1 for 7-inch or 40-prs., which are equally suitable for R.B.L. and M.L. guns; and No. 2, which is smaller and suitable only for R.B.L. guns up to the 20-pr. inclusive. An instrument consists of a curved iron frame about 2 feet long connected by right and left-actioned levers with an iron tube in such a manner that by screwing up a rod which passes down through the tube, the frame can be raised or lowered at will. § 1312, 1625.

Upon this frame a gun-metal plate, corresponding to the calibre of gun must be screwed (except in the case of 6-pr. and 40-pr. guns, when the frames themselves answer the purpose) and the gutta-percha is spread on the plate. When placed in the bore opposite the part of which an impression is wanted, the gutta-percha is pressed out by screwing up the machine.

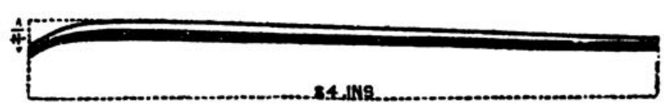
Instruments, sighting, set.—Sighting instruments are intended for special issue only; repairs can generally be effected without them. § 1061, 1096.

Lever, breech-screw.—This may be considered part of the gun, but it is placed in the vocabulary as a separate store, because it can be exchanged when required.

Lever releasing vent-piece.—This is an iron crowbar about 2 feet § 769, 1484.

LEVER FOR RELEASING VENT-PIECE (IRON).

Scale, 1 inch = 1 foot.



10 inches long, for prizing out the vent-piece of a 7-inch gun, whenever it may jam after firing.

Machine, hand-rifling.—There is one hand-rifling machine for each nature of gun,* and all are alike in pattern. They are for the purpose of filing down metal that may be turned up in the bore by the premature bursting of a shell or other cause. § 973, 1096.

The machine consists of—

1 bar, working (*b*), with cross-handle (the 12-pr., 9-pr., and 6-pr. have no cross-handles).
1 block, guide (*d*).
2 cutters, file (*h*).
1 distance piece, in halves, with bolts and nuts (*e*).
1 head, filing, with springs (*c*).
2 screws, fixing.

The filing head is of hornbeam wood, and is grooved like the barrel of the gun. The head is held up to its work by means of strong springs (in the 7-inch there are two, in all other natures one), and a small file can be fitted on either side of the head which is further kept up to its work by a spiral spring placed underneath it.† One side is for grooves, the other

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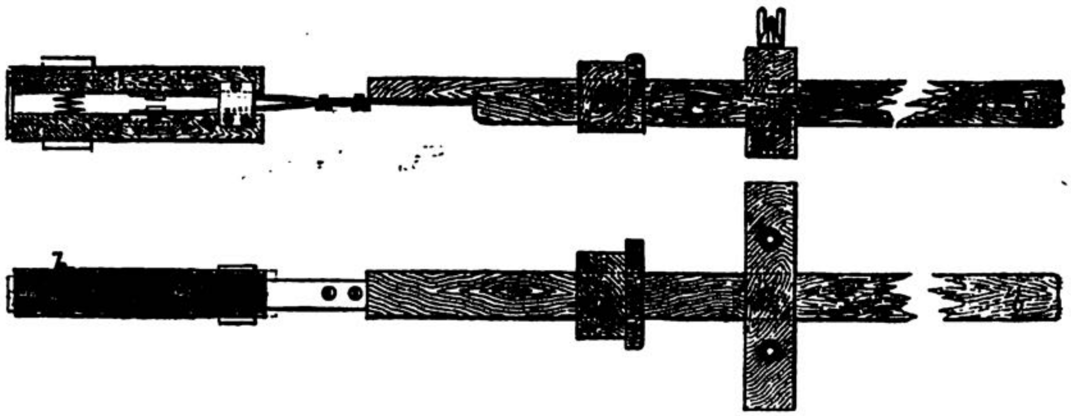
* Except in the case of 9 and 12-pr. guns, for which the same instrument may be used, because the calibre and rifling is the same.

† The 7-inch has no spiral spring, the double spring being sufficient for the purpose.

CHAP. II.

MACHINE, HAND-RIFLING (FOR 6-PR. R.B.L. GUN).

Scale, 1½ inch = 1 foot.



for lands, and the files are shaped accordingly; only one file at a time can be used, which, when fixed, is worked backwards and forwards until the obstruction is removed. The guide block which is placed in the muzzle keeps the bar in the centre, and the distance piece is clamped on the bar at the distance of the flaw from the muzzle.

§ 102, 717, 718. *Patch, metal, elevating.*—These patches are made of gun-metal, and screw into the elevating eye-holes of 12, 9, and 6-pr. guns when fitted for sea service. The 9-pr. patch has a steel screw.

Pins, friction tube.—These pins are of wrought-iron, case hardened, and are inserted 1·3 inches to the left front of the vent on 7-inch vent-pieces, for sea service only. The loop of the quill friction tube fits over the pin, which is made one inch in length, not ·75 inch as shown in the figure for R.M.L. guns at p. 166, to prevent a liability of the loop slipping off.

Pins, keep, lever.—These are part of the breech-closing machinery. *Spare* pins are issued in the proportion of one per 7-inch and 40-pr.; two for all other guns.

Plates, elevating.—These stores are only required with the 20-pr. R.B.L. guns of 13 cwt. when mounted on wrought-iron sliding carriages. The guns should be prepared on both sides of the breech with the necessary screw holes; but only one plate is used, which is triangular, as in the case of the 40-pr. R.M.L. gun.

§ 350, 472, 526, 528. *Rings, copper, vent-piece.*—These have already been described as forming part of the obturation of this class of gun. They have a half dovetail on the inner side, which prevents the passage of the powder gas between it and the vent-piece. It projects from the face of the vent-piece ·05 inch when new, so that it can be refaced two or three times. Small channels are cut on the inside of the ring to allow the confined air to escape when placing it on the vent-piece. *Spare*, two per field gun.

§ 790, 1033. *Rings, Indicator, for 7-inch and 40-pr. R.B.L. Guns.*—See diagram and description at p. 252.

Rings, tappet.—See p. 251.

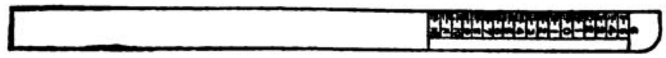
Saddles, metal.—Metal saddles form a rest for the vent-piece of the 7-inch guns, and are attached to the gun in rear of the slot. The saddle for the 72-cwt. gun of A pattern is about 2½ inches shorter than that for the B pattern gun, the breech being shorter, and this is attached by four screws, all other saddles have six. For the 82 cwt.

gun the saddles are stouter than for either of the light 7-inch, and the CHAP. II.
position of the screw-holes is different.

Scale, wood, side.—The wood side scale is used by the Navy for § 1204.
broadside guns for giving elevation only, when the object is obscured

SCALE, WOOD, SIDE.

Scale, 1 inch = 1 foot.



by smoke. It must be used in connection with the ship's pendulum, director, or other means employed to ascertain the heel of the vessel. The method of use has been explained at p. 151, except that no moveable pointer is supplied, and there is no heel scale on the gun; consequently the angle of heel must be either added to or substracted from the elevation required for range.

The side scales are adjusted to the rear chock of the carriage with the zero notch coinciding with a point on the vertical line intersected by the horizontal line cut on the right side of the breech, the gun being horizontal. They are graduated to give 6° depression and 12° elevation, the radius being the distance from the centre of the trunnion to the point of intersection on the side of the breech.

The wood side scale for the 20-pr. of 13 or 15 cwt. has a moveable pointer similar to that used with R.M.L. guns. This scale gives depression down to 20°, and elevation up to 12°. (See figure, next page.)

Screws, set, tangent sight, right hand and left hand.—These are used for § 901, 906,
the purpose of clamping the tangent sight, and pass through bosses in 935, 829,
the tangent sight ring. For the 20-pr. downwards they are attached to 1034.
the guns by a small chain.

Screws, fixing, plates, elevating.—These belong to the 20-pr. of 13 cwt. only; they are used to fasten the elevating plate.

Screws, fixing, crutch.—To attach the crutch to the top of the vent- § 688.
piece.

Screws, fixing, metal saddle.—To attach the saddle of 7-inch guns.

Screws, preserving.—To occupy the holes for the crutch, friction tube § 485.
pin, and lanyard guide, when the gun is used for land service, *and mounted.* When dismounted these holes should be filled up with grease.

Sights, instructional, wood.—Enlarged models of the tangent sights § 1480.
either hexagonal or rectangular are issued on demand.

Sockets, metal.—Gun-metal sockets are supplied for the 7-inch guns. § 1481.

Straight-edge.—The straight-edge is of steel, $18'' \times 1\frac{1}{2}'' \times \frac{3}{10}''$. It is § 1016.
used for testing the face of breech-screw, back of the vent-piece, &c.

Vent-piece.—For field batteries two vent-pieces per gun are issued § 1185.
(one carried in the gun, one at the side of the trail), and two in addition per battery. Garrison and siege batteries have three per gun. *Vent-piece, drill, Marks I, II, and III,* are issued for use with 40-pr. guns for drill purposes. The marks differ in the method of attaching the metal face and minor details only.

Wrench.—A wrench is required to attach the elevating racks and plates to the 20-pr. guns, when mounted on the decks of ironclads. This is the same as wrench No. 4 used for R.M.L. guns.

CHAP. II.

20-PR. R.B.L. GUN, 13 OR 15 CWT.

Scale, wood, ¼ size.

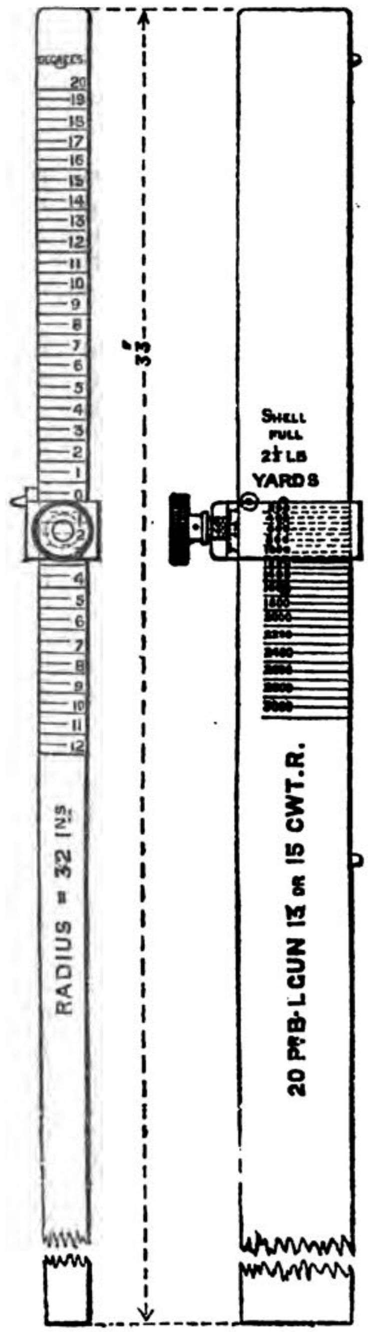


TABLE XXVIII.—TANGENT SIGHTS FOR R.B.L. GUNS.

Gun.	Angle of Correction for Drift.		Radius Distance.	Latest Mark of Sight.	Reference. §	Graduations.			Deflection, Right and Left.		Remarks.
						Degrees.	Yards.	Fuze Tenths.			
	°	′	inches.						°	′	
7-inch 83 cwt.	2	16	45	III	1476	15	3,600	24	0	30	
7-inch 72 cwt.	2	16	41·2	II	1254, 716	10	..	..	0	30	Hexagonal.
40-pr. 35 cwt.	2	16	45	III	1476	15	3,800	25	0	30	
20-pr. 32 cwt.	2	16	45	III	1476	15	3,800	25	0	30	The side-closing guns use this pattern of sight.
20-pr. 16 cwt.	2	16	36·2	II	1254, 998	13	3,500	..	0	30	
20-pr. 13 and 15 cwt. ..	2	16	23·45	II	1254, 903	15	3,000	..	0	30	
12-pr. 8 cwt.	2	16	32·375	II	1254, 829	10	3,400	..	0	30	Hexagonal.
9-pr. 6 cwt.	2	16	23·45	II	1254, 905	15	3,000	..	0	30	
6-pr. 3 cwt.	2	16	23·45	II	1254, 906	12	3,000	..	0	30	

PART III.

CHAPTER III.

DIFFERENT NATURES OF R.B.L. GUNS IN THE SERVICE.

R.B.L. guns in the service.—7-inch of 82 cwt.—7-inch of 72 cwt.—40-pr. 32 cwt.—40-pr. 35 cwt.—40-pr. side-closing gun.—20-pr. 16 cwt.—20-pr. 15 cwt. —20-pr. 13 cwt.—12-pr. 8 cwt.—9-pr. 6 cwt.—6-pr. 3 cwt.—Table of dimensions, rifling, breech fittings, &c., for all R.B.L. guns in the service.—Table of sights, fittings, and stores for each nature of R.B.L. gun.—Table of stores for guns mounted on special carriages.

A FEW remarks are here offered in connection with each nature of R.B.L. gun in the service, to point out peculiarities in their construction, and any special sights, fittings, or stores which may be associated with them.

7-inch Guns.

There are two natures of 7-inch: the heavier, weighing 82 cwt., was the one first introduced into the service, a number having been issued in 1861; but the lighter gun, of 72 cwt., was of earlier construction, though not completed and issued till 1863. From experience gained in the case of the 40-pr. gun, which preceded the 7-inch, it was thought advisable to improve upon the original design, and to add a strengthening coil over the powder chamber. Before this was decided, however, about 76 guns of the lighter description had become too far advanced for the change; these were afterwards utilised by completion as 72-cwt. guns for land service.

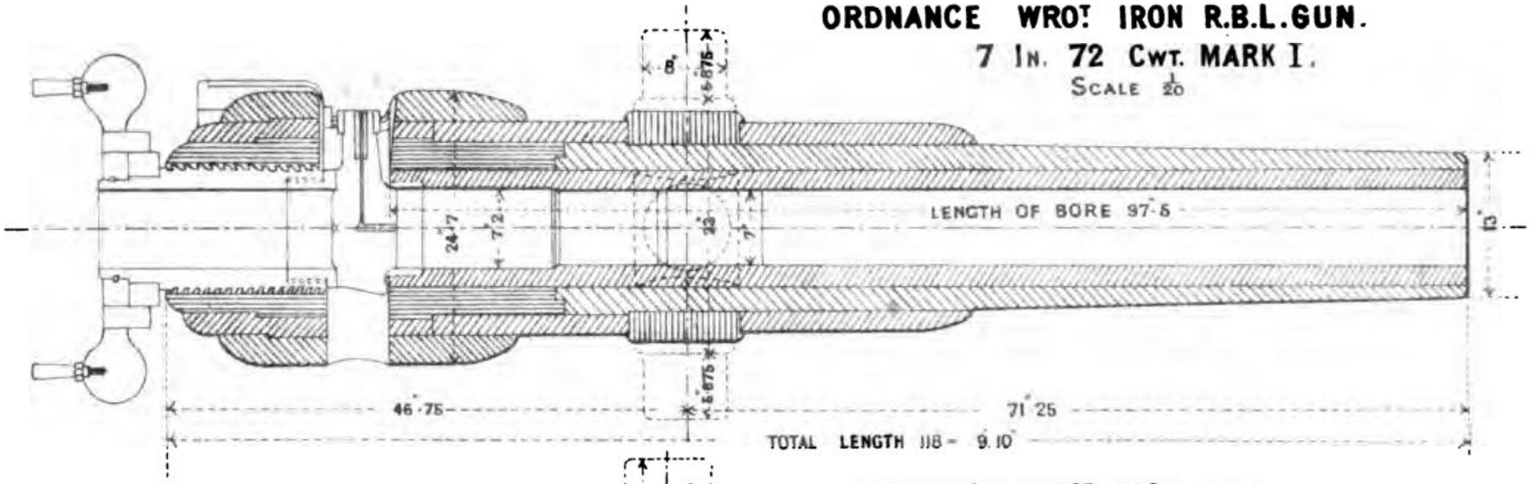
7-inch Gun of 82 cwt.

7-inch, 82 cwt. § 985. This gun consists of an A-tube, a forged breech-piece, a B-tube which extends from the breech-piece to the muzzle, a trunnion ring, and six exterior coils.

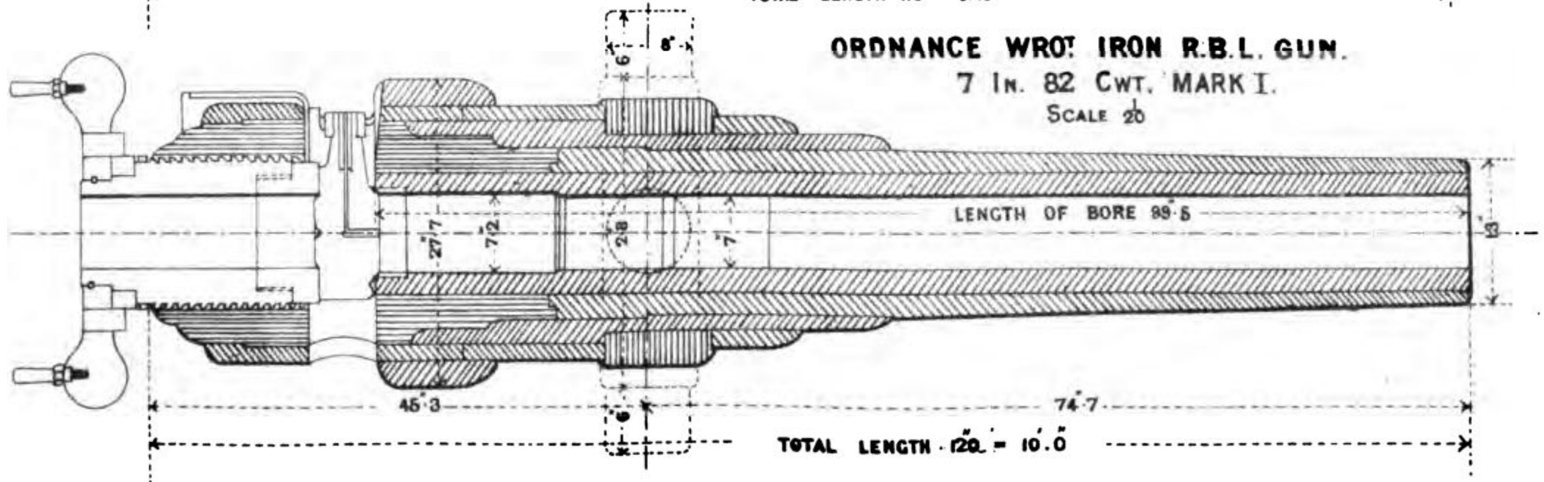
It has been used largely for land and sea service, but not being sufficiently powerful for the penetration of armour it was replaced in the naval service by heavier muzzle-loading guns.

§ 466, 899. It was first called a "100-pr."; but afterwards, in 1861, when the weight of projectile was increased to 110 lbs. it was designated the 110-pr; finally it was termed the 7-inch of 82 cwt.

To face page 266



ORDNANCE WROT. IRON R.B.L. GUN.
7 In. 72 Cwt. MARK I.
Scale $\frac{1}{20}$

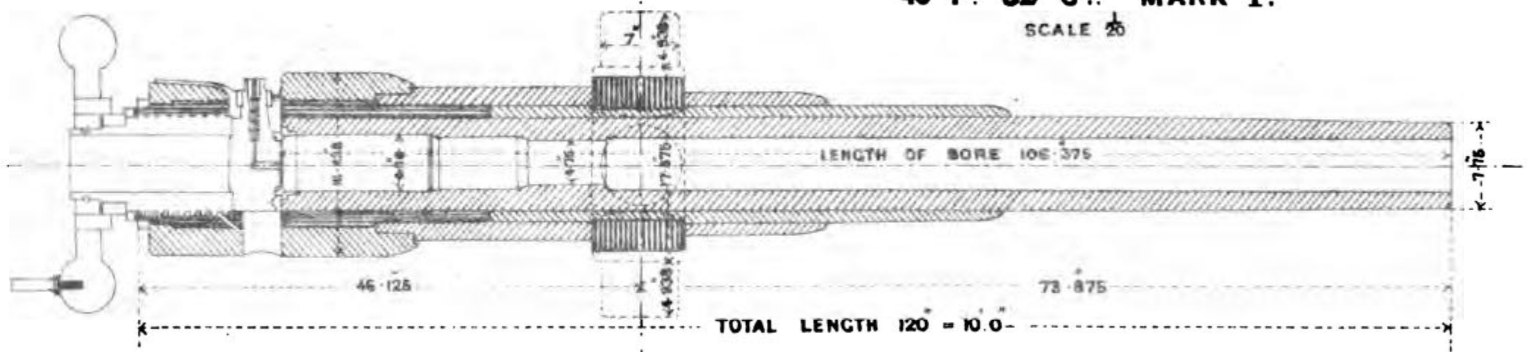


ORDNANCE WROT. IRON R.B.L. GUN.
7 In. 82 Cwt. MARK I.
Scale $\frac{1}{20}$

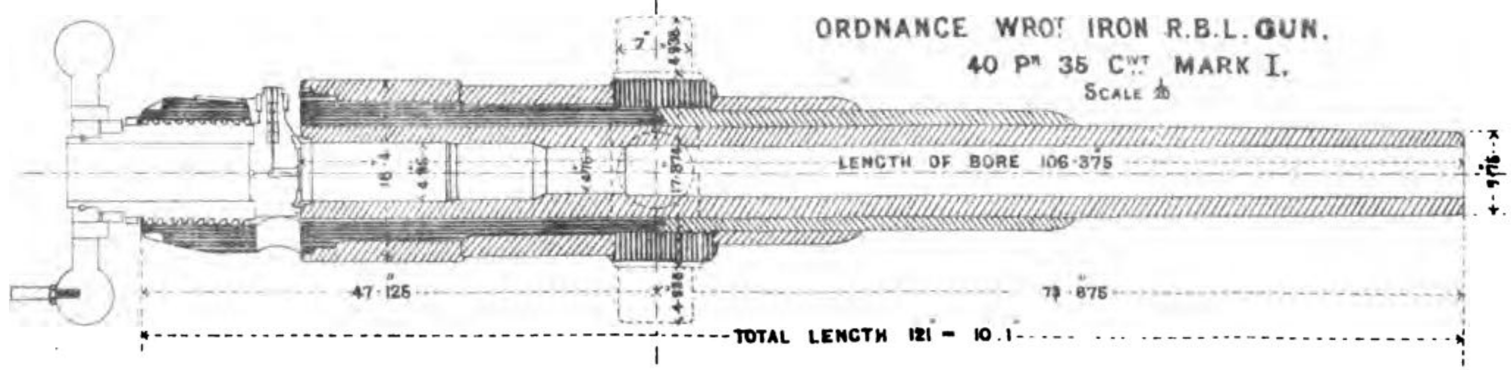
Dangerfield. Lith 22. Bedford St. Covent Garden. 7878.

To face page 267.

ORDNANCE, WROT IRON R.B.L. GUN.
40 Pr 32 Cwt MARK I.
SCALE $\frac{1}{20}$



ORDNANCE WROT IRON R.B.L. GUN.
40 Pr 35 Cwt MARK I.
SCALE $\frac{1}{20}$



DANGERFIELD, LITH 22, BEDFORD ST COVENT GARDEN.

7-inch Gun of 72 cwt.

This consists of the same parts as the 7-inch of 82 cwt., except that there are only four coils; but it differs in dimensions and outline, especially at the breech end of the gun. 7-inch, 72 cwt. § 598.

There are two patterns, marked respectively "A" and "B"; the former being 2 inches longer in the barrel than the B pattern, and 2 inches shorter in the breech.

They have been issued for L.S. only.

The designation was changed in 1863, from the "light 110-pr." to the 7-inch of 72 cwt.

40-pr. Guns.

There are two natures of 40-pr. guns, which correspond in general construction with the two natures of 7-inch.

The calibre is 4·75 inches; and both patterns have been issued for land and sea service.

40-pr. Gun of 32 cwt.

This gun consists of an A-tube, forged breech-piece, B-tube, trunnion ring and three coils. The muzzle part of the barrel forms the chase of the gun, for it is not covered by any exterior layer of coiled iron. 40-pr., 32 cwt. § 901.

The tangent sights are placed in a socket ring, which is fixed to the breech by a small screw, so as to give them an inclination of 2° 16′ to the left.

These guns were recommended in 1859 for the navy as broadside or pivot guns, but they would now be used only by the land service for batteries of position and garrison purposes.

A few of these guns have a trunnion ring made of *cast iron*; these may be known by the face of the trunnion being conically bored out in the centre.

40-pr. Gun of 35 cwt.

This gun consists of the same parts as the 40-pr. of 32 cwt., but it has a longer and stronger breech-piece, which is rounded off at the end. 40-pr., 35 cwt. § 902.

The strengthened pattern was introduced in 1860 more as a matter of precaution than from any symptoms of weakness in the lighter gun.

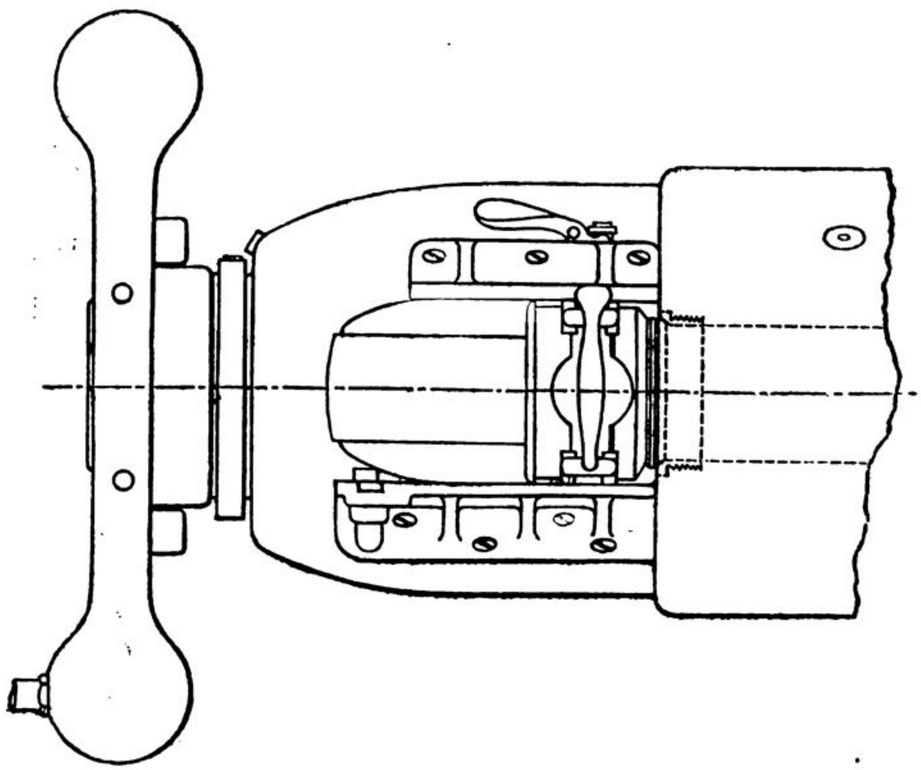
It is used for the same purposes as the 40-pr. of 32 cwt., and the fittings are made interchangeable with the exception of the breech-screw which has a different thread, the pitch being ·7″ in this case instead of a ·9″ as in the earlier gun.

40-pr. of 35 cwt., Side-Closing Gun.

In 1880 it was proposed to convert the 7-inch of 82-cwt. and the 40-pr. of 35 cwt. into "side-closing" guns; experimental pieces were accordingly prepared and submitted for trial. These answered exceedingly well, the saving of labour being very great especially in the case of the 7-inch; approval for service, however, has only been given for a limited number of the 40-pr. guns, which will be mounted on elevated carriages. The experiments embraced other systems of obturation, change of powder, and a copper band on the shell, to develop an increase of power, but these points involved new ammunition and considerable expense, so it was ruled that no change should be made which would prevent the existing ammunition from being used up. 40-pr. side-closing gun. § 4410.

CHAP. III.

BREECH END OF GUN.



The alteration consists in bringing the vent-piece slot to the right side, by turning the trunnion ring to the left. This can be done by heating the ring very carefully, so as to loosen its grip, when the turn can be made through a quarter of the circle, which must be previously marked on the gun.

The gun is then fitted with a solid stopper or breech block. An upper and lower gun-metal bracket is affixed to the slot, between which the block slides, its movement in and out of the gun being limited by a spring stop which is worked by a small lever above. The breech-block is fitted with a copper ring like a vent-piece. The gun has a radial vent through a copper bush on the right side 6·5 inches from the end of the bore and inclined at an angle of 45° to the plane of the axis of the gun and its trunnions.

A special tin cup extractor is required for use with this side-closing gun; but in other respects the same sights and stores are employed as those which are supplied for the original gun.

20-*pr. Guns.*

There are three natures of 20-pr. guns, weighing 16, 15 and 13 cwt. respectively. The calibre is 3·75 inches in all.

20-*pr. Gun of* 16 *cwt.*

20-pr., 16 cwt. § 998.

This gun consists of an A-tube, a forged breech-piece, a trunnion ring, and five coils. These and all smaller screw guns have no B-tube, not even like the 40-pr., in which it extends half-way down the chase.

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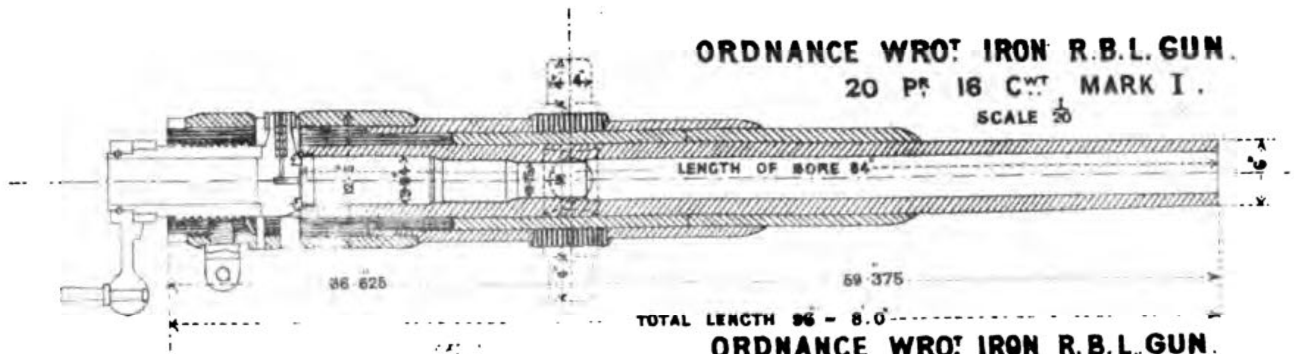
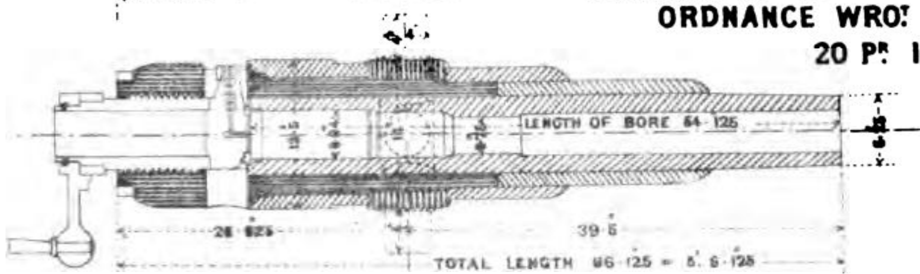
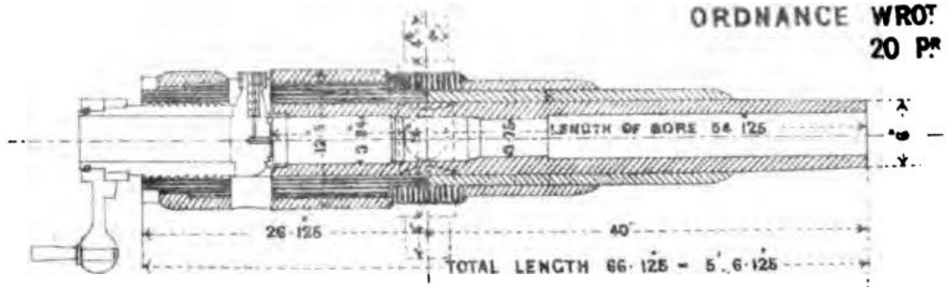
ORDNANCE WROT IRON R.B.L. GUN.
20 PR 16 CWT MARK I.
SCALE $\frac{1}{20}$



ORDNANCE WROT IRON R.B.L. GUN.
20 PR 15 CWT MARK I.
SCALE $\frac{1}{20}$



ORDNANCE WROT IRON R.B.L. GUN.
20 PR 13 CWT MARK I.
SCALE $\frac{1}{20}$



DANGERFIELD. LITH 22 BEDFORD ST COVENT GARDEN

It was originally made for a 25-pr, and recommended as such for a light gun of position; but subsequently it was resolved to assimilate this piece to the 20-pr. guns, in order to use the same ammunition. It has only been used for L.S. CHAP. III.

20-*pr. Gun. of* 15 *cwt.*

This piece was adopted for the Navy in 1859. It is $2\frac{1}{2}$ feet shorter than the L.S. gun, and differs also slightly in construction. There are but three coils: the breech-piece is not supported behind the vent-piece slot; and there is a raised coil over the chamber. 20-pr., 15 cwt. § 904.

20-*pr. Gun of* 13 *cwt.*

This also is a S.S. gun, having been recommended in 1859 for a "pinnace gun," and for field marine service. In dimensions it resembles the 15-cwt. gun, but in construction the land service piece. It has four coils, and the breech-piece is covered in rear of the slot with a coil of wrought iron. 20-pr., 13 cwt. § 903.

The 13-cwt gun is still used on the upper decks of ironclad ships, and is mounted on a carriage which allows 20° elevation or 30° depression. When so used it is fitted on the right side with a gun-metal elevating plate and a steel pivot for the elevating rack, similar to that used with heavy R.M.L. guns.

The vent-piece, breech-screw, and stores generally are interchangeable amongst all the 20-pr. guns; but there are different sights for the land and sea service pieces on account of the different lengths of the sighting radius.

Neither of the S.S. guns can approach the longer piece of 16 cwt. in power or accuracy of shooting. With the same charge the muzzle velocity of the L.S. gun is 1,130 f.s., while that of the S.S. guns is only 1,000.

12-*pr. Gun of* 8 *cwt.*

There is now only one kind of 12-pr. gun, and this is used for both land and sea service. 12-pr.

The calibre is 3 inches.

The gun consists of an A tube, a forged breech-piece, trunnion ring, and three coils; being similar in construction and outline to the 20-pr. L.S. gun.

It was recommended in 1858 for the equipment of field artillery, and it was subsequently adopted by the Navy, as a boat or field marine gun; but the naval pattern was 12 inches shorter, and was made without a grip at the muzzle, which was given at first to the land service gun to centre the projectile at the muzzle, and thereby obtain accurate shooting. § 401.

In 1863 an universal pattern was introduced, the L.S. pattern being altered; but the shooting of the 12-pr. gun was very much impaired by this change. The vent slot was widened to take a thicker and stronger vent-piece, an alteration which caused a portion of the breech-screw to become exposed even when tightly screwed up. A leather collar was then made to cover the thread, which thus became liable to damage and to injury by taking up grit. § 829. § 939. § 826.

The tangent sights are of exceptional pattern, being hexagonal gun-metal bars. For this and all smaller natures of R.B.L. guns, the trunnion sights are of screw pattern.

CHAP. III.

9-*pr. Gun of* 6 *cwt.*

9-pr., § 905, 474, 529.

This gun was introduced in 1862 for the Horse Artillery. The Navy also adopted it afterwards for a boat and field marine gun.

The calibre is 3 inches, being the same as for the 12-pr. gun. On emergency the 9-pr. ammunition, or at least the case shot, might be fired from the 12-pr. gun; but the converse can never be done, for both the shot and the cartridge would be found too long for the chamber in the 9-pr. gun.

6-*pr. Gun of* 3 *cwt.*

6-pr., § 906.

This gun was recommended in 1858 for mountain service, but when found rather too heavy its use was restricted to colonial batteries. The navy also took it as a boat and field marine gun.

The calibre is 2·5 inches.

In construction and general appearance it resembles the 9-pr., but there is only one exterior coil which is placed in front of the trunnions; the breech-piece supplies all the metal over the A tube in rear.

The sights, fittings, and stores are similar to those used with the 9-pr. gun, but of course they are not interchangeable.

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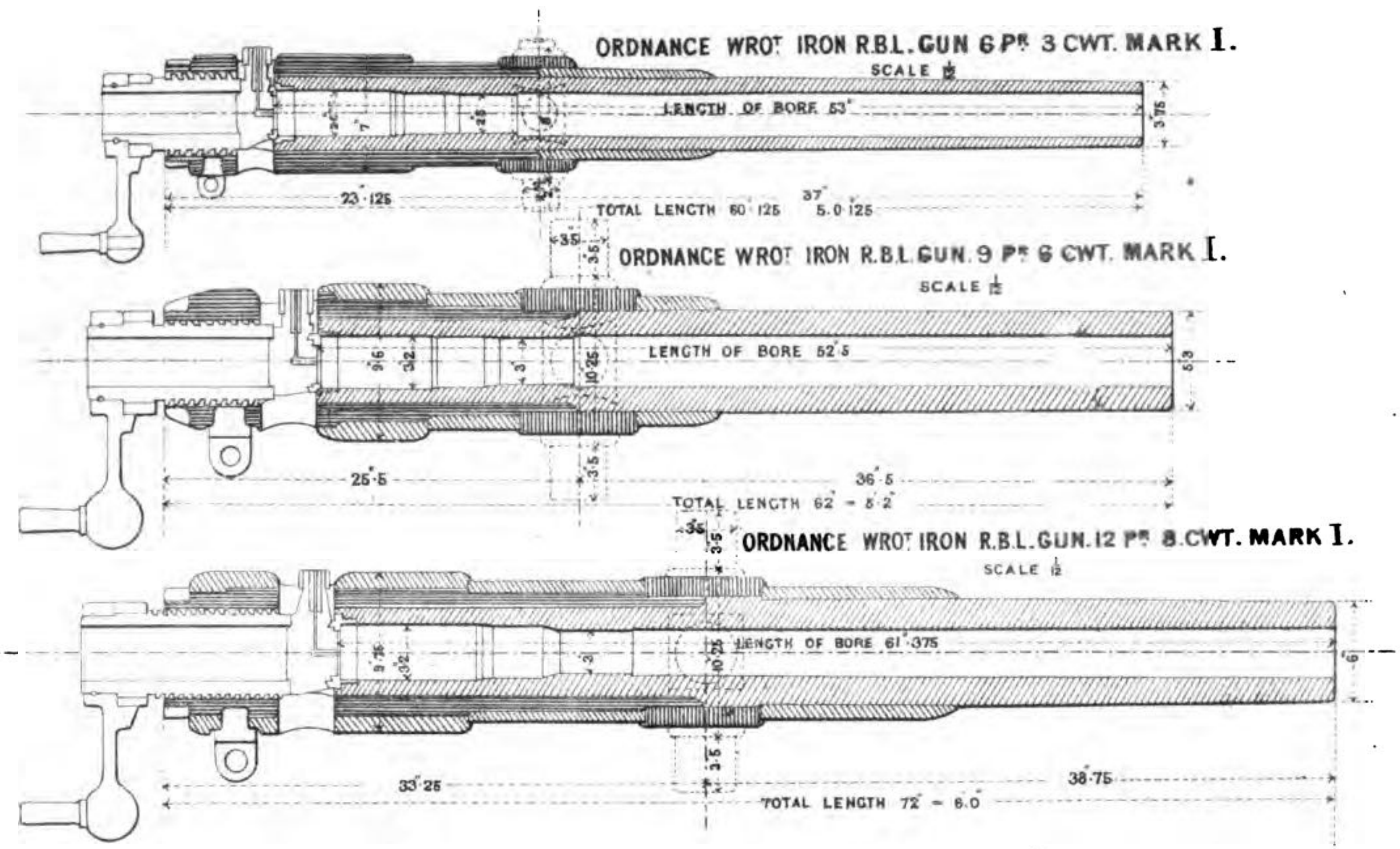

TABLE XXIX.—SHOWING DIMENSIONS, RIFLING, BREECH FITTINGS, &c., OF R.B.L. GUNS.

Nature.		Calibre.	Length.					Breech-screw. (Complete with fittings.)		Vent-piece.	Rifling.					Preponderance.	Remarks.
			Nominal.†	Barrel.		Powder Chamber.	Shot Chamber.	Weight.	Pitch of Thread.	Weight.	Twist.	Grooves.			Width of lands.		
												Number.	Depth.	Width.			
		"	"	"	cals.	"	"	cwt. qrs. lbs.	"	cwt. qrs. lbs.	cal.		"	"	"	cwt. qrs. lbs.	
7-inch	82 cwt.	7	120	99·5	14·2	16·0	9·0	5 2 18	1·4	1 0 24	U 1·37	76	·06	·166	·1233	6 3 16	
	72 cwt.	7	118	97·5	13·9	14·25	9·0	5 2 18	1·4	1 0 24	U 1·37	76	·06	·166	·1233	7 3 27	
40-pr.	35 cwt.*	4·75	121	106·375	22·4	13·5	7·0	2 1 13	·7	0 2 3	U 1 36½	56	·06	·166	·1	4 3 0	
	32 cwt.	4·75	120	106·375	22·4	13·5	7·0	2 1 13	·9	0 2 3	U 1·36½	56	·06	·166	·1	5 1 19	
20-pr.	16 cwt.	3·75	96	84·0	22·3	12·0	6·0	1 0 8¾	·5	0 0 27¾	U 1·38	44	·06	·166	·1	2 0 11	
	15 cwt.	3·75	66·125	54·125	14·4	11·0	6·0	1 0 8¼	·5	0 0 27¾	U 1·38	44	·06	·166	·1	1 2 0	
	13 cwt.	3·75	66·125	54·125	14·4	11·0	6·0	1 0 8¼	·5	0 0 27¾	U 1·38	44	·06	·166	·1	1 1 24	
12-pr. 8 cwt.		3	72	61·375	20·4	8·5	3·0	0 2 12	·5	0 0 15	U 1·38	38	·045	·148	·1	1 3 3	
9-pr. 6 cwt.		3	62	52·5	14·1	7·0	3·0	0 2 6¾	·5	0 0 14¾	U 1 38	38	·045	·148	·1	0 2 26	
6-pr. 3 cwt.		2·5	60·125	53·0	21·2	7·0	2·5	0 1 10	·5	0 0 8¼	U 1·30	32	·045	·148	·1	0 1 27	

* These dimensions are unaltered in the side-closing guns.

† From face of muzzle to extreme end of breech, not including breech-screw.

CHAP. III.

TABLE XXX.

Sights, Fittings, and Stores, for R.B.L. Guns.

Stores.	7-inch Gun. 82 cwt. Sea Service.	7-inch Gun. 82 cwt. Land Service.	7-inch Gun. 72 cwt. Land Service.	40-pr. Sea Service.	40-pr. Land Service.	20-pr. Sea Service.	20-pr. Land Service.	12-pr. Land Service.	9-pr. Land Service.	6-pr. Land Service.	Remarks.
Bands, elevating (with pivot)	—	—	—	—	*1	—	—	—	—	—	*Mark II.
Bearers, shot	1	1	1	—	—	—	—	—	—	—	
Bits, vent, Armstrong	1	1	1	1	1	1	1	1	1	1	Issued in certain proportions as required.
Blocks, breech drill	—	—	—	—	1	—	—	—	—	—	Side-closing guns only.
Blocks, breech	—	—	—	—	1	—	—	—	—	—	
Brackets, guide, upper	—	—	—	—	1	—	—	—	—	—	
Brackets, guide, lower	—	—	—	—	1	—	—	—	—	—	
Bushes, breech, thick (iron)	1	1	1	—	—	—	—	—	—	—	
Bushes, breech, thin (iron)	1	1	1	—	—	—	—	—	—	—	
Bushes, breech, copper	—	—	—	1	1	1	1	1	1	1	
Bushes, copper, vent-piece, sets ..	1	1	1	1	*1	1	1	1	1	1	*Except side-closing.
Clamps, tangent sight, A	—	—	—	2	2	—	—	—	—	—	
Clamps, tangent sight, C	2	2	—	—	—	—	—	—	—	—	
Crutches, iron	—	—	—	1	—	1	—	—	—	—	
Extractors, tin cup, crosshead	—	—	—	—	1*	—	—	—	—	—	*For side-closing guns only.
Extractors, tin cup, hook	—	1	1	—	1	—	1	1	1	1	
Extractors, tin cup, S.S. lever	1	—	—	1	—	1	—	—	—	—	
Eyes, elevating (complete with bolt, pin, and washer)	—	—	—	—	—	—	1	1	1	1	
Implements, facing, set	1	1	1	1	1	1	1	1	1	1	
Instruments, taking impressions of bore of guns, No. 1 ...	1	1	1	1	1	—	—	—	—	—	
Instruments, taking impressions of bore of guns, No. 2 ...	—	—	—	—	—	1	1	1	1	1	
Lanyard guide	1	—	—	1	—	1	—	—	—	—	
Levers, breech-screw	1	1	1	1	1	1	1	1	1	1	
Levers, vent-piece, lifting	1	1	1	—	—	—	—	—	—	—	
Levers, vent-piece, releasing (iron) ...	1	1	1	—	—	—	—	—	—	—	
Machines, hand-rifling	1	1	1	1	1	1	1	1	1	1	
Pieces, vent, service	1	1	1	(a) 1	(a) 1	1	1	1	1	1	
Pieces, vent, drill	—	—	—	—	1	—	—	—	—	—	
Pins, friction tube	1	—	—	—	—	—	—	—	—	—	
Pins, keep, lever	2	2	2	2	2	2	2	2	2	2	For use with 20-pr. when mounted on upper decks.
Pins, keep, pivot, plate elevating ...	—	—	—	—	—	1	—	—	—	—	
Pivots, elevating "C"	—	—	—	—	—	1	—	—	—	—	
Plates, elevating	—	—	—	—	—	1	—	—	—	—	
Rings, vent-piece	—	—	—	1	1	1	1	1	1	1	
Rings, indicator	1	1	1	1	1	—	—	—	—	—	
Rings, tappet	1	1	1	1	1	1	1	1	1	1	
Saddles, metal	1	1	†1	—	—	—	—	—	—	—	
Scales, wood, side	1	—	—	1	—	1	—	—	—	—	
Screws, breech	1	1	1	†1	†1	1	1	1	1	1	
Screws, set, tangent sight, right hand	—	—	—	—	—	1	1	1	1	1	
Screws, set, tangent sight, left hand	—	—	—	—	—	1	1	1	1	1	
Screws, fixing, crutch	—	—	—	2	—	2	—	—	—	—	
Screws, fixing, saddle	6	6	4	—	—	—	—	—	—	—	
Screws, fixing, plate, elevating ...	—	—	—	—	—	3	—	—	—	—	
Screws, preserving, crutch	—	—	—	—	2	—	2	2	2	2	
Screws, preserving, plates, lanyard guide...	—	1	1	—	—	—	—	—	—	—	
Screws, preserving, pin, friction tube ...	—	1	—	—	1	—	—	1	1	1	
Screws, preserving, plates, elevating ...	—	—	—	—	—	6	—	—	—	—	
Sights, instructional, wood	—	—	—	—	—	—	1	—	—	—	At certain stations only.
Sights, tangent	2	2	2	2	2	2	2	2	2	2	
Sights, fore	2	2	2	2	2	2	2	2	2	2	
Straight-edges, for testing breech-screws and vent-pieces	1	1	1	1	1	1	1	1	1	1	Issued in certain proportion required.
Wrench, No. 4	—	—	—	—	—	1	—	—	—	—	

Note.—All the above stores are interchangeable with guns of the same nature, excepting those marked thus.†

(a) Not used with side-closing guns.

TABLE XXXI.

STORES for R.B.L. GUNS when mounted on SPECIAL CARRIAGES.

Articles.	Ordnance, R.B.L. — 7-inch, 82 cwt. — L.S.	7-inch, 82 cwt. — Mounted on Moncrieff carriage, Mark II.	7-inch, 82 cwt. — Mounted on converted 7-inch M.L. 6½ ton. Naval carriages.	7-inch 72 cwt. L.S.	40-pr. — 32 and 35 cwt.	40-pr. — Side-closing gun.	20-pr. 16 cwt.	Spare.
Bolt eye for trunnion	—	2	—	—	—	—	—	1 to every 5 guns so mounted.
Block, breech, with handle, &c., complete	—	—	—	—	—	1	—	2 to each gun, and 2 copper rings extra per gun.
Brackets, bronze guide, lower with stud stop, movable spring, spiral, handle, keep-pin, and 5 screws, fixing ...	—	—	—	—	—	1	—	1 to every 10 or less number of guns and 2 springs, spiral, per gun.
Brackets, bronze guide, upper, with 3 screws, fixing	—	—	—	—	—	1	—	1 to every 10 or less number of guns.
Clamps, tangent sight ... A	—	—	—	—	2	2	—	1 to every 10 or less number of clamps.
Clamps, tangent sight ... C	2	2	2	2*	—	—	—	
Eye, elevating, complete, with bolt, washer, and keep-pin	—	—	—	—	—	—	1	1 keep-pin to every gun.
Plates, elevating, with bolt washer, keep-pin and screws, fixing, breech	—	1	—	—	—	—	—	1 keep-pin to every gun.
Plates, elevating, with pivot, keep-pin, and screws, fixing, left ...	—	—	1	—	—	—	—	? pivots to every 10 or less number of guns as fitted.
Plates, elevating, with pivot, keep-pin, and screws, fixing, right ...	—	—	1	—	—	—	—	
Pieces, vent	1	1	1	1	1	—	1	1 to every 20-pr. 2 to every 40-pr. and 7-inch, and 2 copper rings per gun.
Plates, trunnion	—	1	—	—	—	—	—	
Rings, indicator	1	1	1	1	1	1	—	
Saddles, metal, with screws, fixing ...	1	1	1	1	—	—	—	
Screws, breech, complete, with tappet ring, 2 keep-pins, and lever	1	1	1	1	1	1	1	1 breech-screw complete to every 10 or less number of guns. and 1 tappet ring, and 1 keep-pin per gun.
Screws, set, tangent sight	—	—	—	—	—	—	2	
Screws, preserving, brackets, guide .	—	—	—	—	—	8	—	
Screws, preserving, eye-bolt, trunnion	—	2	—	—	—	—	—	
Screws, preserving, plate, elevating...	—	5	8	—	—	—	—	
Screws, preserving, pin, friction tube	1	1	1	1	—	—	—	
Screws, preserving, lanyard guide ...	1	1	1	1	—	—	—	
Screws, preserving, sight, reflecting, trunnion ...	—	3	—	—	—	—	—	
Sights R.B.L., reflecting, counter-weight carriage, Mark II, lower	—	1	—	—	—	—	—	1 glass mirror per gun. 1 mirror, with frame, &c., complete, to every 10 or less number of guns.
Sights R.B.L., reflecting, counter-weight carriage, Mark II, upper	—	1	—	—	—	—	—	Ditto.
Sights R.B.L., fore, F	2	2	2	—	2	2	2	1 to every 10 or less number of sights of the same nature.
Sights R.B.L., fore	—	—	—	2	—	—	—	
Sights R.B.L., tangent	2	2	2	2	2	2	2	
Stud, retaining, breech-block, complete	—	—	—	—	—	1	—	2 springs, spiral, to each gun.

* Not required if fitted with a "saddle, metal," having "horns."

PART III.

CHAPTER IV.

B.L. ORDNANCE.*

The interrupted screw.—Obturation.—The "cup" system.—Brass discs.—Instructions regarding cup-obturation.—Large cups.—De Bange method of obturation.—Spindle attachment.—Lever with cam and locking arrangement.—Endurance of the pad.—General remarks on B.L. guns.—Length.—Chase.—Swell at the muzzle.—Bell-mouth.—Enlarged powder chamber.—Rifling.—Marks and lines.—Guns with cup-obturation.—Venting.—General description of sights.—Sights with square tangent bar.—Triangular sights.—Acorn fore-sights.—Special S.S. sights.—Details of the 12-pr.—4-inch 13 cwt.—4-inch 22 cwt., I, II, III and IV.—Slide with vent-masking hood.—Slide with percussion lock.—5-inch, I and II.—6-inch 80 cwt.—6-inch, II and III.—7-inch.—8-inch, I, II, III, and IV.—9·2-inch, I, II, and III.—10-inch.—12-inch, I, II, III, and IV.—13·5-inch.—16·25-inch.—Table of dimensions, rifling, &c.—Table of tangent sights for B.L. guns.—Table of sights, fittings, and stores issued with each nature of gun.—Table of ballistics.

The interrupted screw. In all the B.L. guns of new type in our service, the breech-action, or method of opening and closing the breech, is the same, viz: the interrupted screw system. This consists of a solid breech-block of steel, furnished with a screw-thread of the requisite strength and pitch, while the gun is prepared with a similar female screw to receive it: the surface of the block is then divided longitudinally into six or eight equal parts, and the screw-thread is entirely removed from alternate portions by a planing machine; in the gun alternate portions are slotted away, but the parts which correspond with the smooth portions on the block are left in relief, and those which are opposite to the screw-thread are cut away. When mutually prepared in this manner, the block can be pushed into the gun or drawn out with direct motion, while a turn of one-sixth or one-eighth of a circle (after being pushed in) is sufficient to bring all the screw-threads into gear. The bearing surface and strength of the screw is obviously reduced by one-half, but the requisite strength can be easily provided by regulating the length of the block; such length cannot appreciably affect the time occupied in opening or closing the breech. Additional mechanism may be supplied for working the heavier natures of ordnance, but extra leverage or power does not alter this principle of closing the breech.

Obturation. Two systems of obturation will be found in guns of this class, which for brevity may be distinguished as the "Elswick Cup" and the "De Bange" systems.

* The designation of this class of ordnance has been changed since their first introduction. The term "interrupted screw" has been dropped; they are now called simply "B.L. guns," the old breech-loading guns retaining their name of "R.B.L. guns."

The Elswick cup system.

The "Cup" system consists of a shallow steel cup which is bolted axially to the face of the breech-screw by means of a spindle and nut. The back of the cup is flat, while the face of the breech-screw is made slightly convex. A copper ring is let into the gun behind a step in the chamber, which encircles the cup when the breech has been closed. The cup is set "home" into contact with this copper ring by the travel of the breech-screw; then the pressure of gas on firing the charge drives back the outer portion of the cup upon the curved face of the block, so that its flange is forced out against the ring, and bedding itself in the copper it prevents all escape of the gas.

Brass discs.

Although the best silver steel is employed for these cups, they are apt to take a permanent set to the curved face of the block: thin discs of brass of smaller diameter than the outside of the cup are therefore supplied to guns which have this obturation to be placed on the spindle as packing just behind the back of the cup; their object is to carry the outer edge of the cup away again from the block.

Instructions.

Both the cup and copper ring should be kept perfectly clean in action for grit and dirt will prevent that close contact which is necessary to seal up the gas. With the smallest escape the cup will get scored round the edge, and the gas rushing through a furrow so made will soon damage the ring in the gun. So that any small fissure on the cup should not remain opposite the same spot on the ring for two or more consecutive rounds: neglect of this point may soon lead to deep scoring, which would render the gun unfit for use. A damaged cup may be easily exchanged, but renewal of the ring in the gun is an operation which can only be performed by skilled artificers with suitable tools. A cup tightly fixed on the block would most likely produce a gas-worn ring in a very short time, and the furrowed ring in its turn would be the means of destroying every new cup; so it is highly important with this obturation to observe cleanliness both on the copper ring and rim of the cup, and especially to watch the state of the ring so as to maintain perfect smoothness of surface.

Large cups.

Again, the copper ring is liable to be expanded or set out to a larger diameter by repeated pressure until the obturation is imperfect from inability of the cup to press tightly against the copper ring. To meet this cause of failure cups are supplied ·005 of an inch larger in diameter than the service cups, for which the latter can be exchanged when required. If the soft metal in the ring yields further to the pressure of these cups of large size there is no remedy but renewal of the ring; and this is a difficult operation which even trained artificers may fail to carry out satisfactorily.

From these remarks it will be seen that there are serious objections to the cup system, and consequently another method was recommended by the Superintendent R.G.F., which is known as the De Bange obturation. This after full trial was adopted in 1882 for all natures of B.L. guns.

De Bange obturator.

The De Bange obturator consists of a mushroom-headed spindle of steel affixed to the breech block by an axial stem, with a pad comprising a wad and a pair of compound metal discs. The face of the breech-screw in this case is flat, and between this smooth surface and the back of the *tête mobile* (as the head of the spindle is called which forms the end of the bore) the wad and discs are arranged. The wad is made of asbestos, worked up with grease to a proper consistency and enclosed in a strong canvas cover; it is reduced to shape and pressed in a hydraulic machine; afterwards it is subjected to higher pressure in the gun by firing heavy charges at proof. This wad is enclosed between two plates of tin, the outer angles of which are protected by

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rings of steel.* At first an outer ring was split to give freedom for expansion, but experience has shown that this is unnecessary if the rings are of proper diameter. There is no preparation in the gun except a slight cone as a seat for the obturator when pushed home in the gun, and the surface of the pad is provided with a similar taper to ensure a good fit.

Action of the De Bange obturator.

The action of the De Bange obturator is this:—When the breech-block is pushed into the gun the *tête mobile* and obturator enter the chamber with perfect ease; on turning the breech-screw, the pad is brought into contact with its coned seat in the gun, and pressed home by the travel or pitch of the screw. The bore is then perfectly closed by a species of buffer in contact all round the circumference, while the *tête mobile* forms a loose end to receive the force of the gas on discharge. On firing the gun the pressure acts on the steel mushroom head, and this squeezes the pad against the breech-block, causing it to expand laterally; from symmetry of form and position this expansion must be radial to the axis and equal in every direction, and experience has proved that it is sufficient to prevent escape of the gas. After the pressure is removed elasticity comes into play, and the obturator can be withdrawn from the cone by a straight pull, which can be given as soon as the screw is unlocked.

Simplicity and endurance.

The simplicity of this obturation is evident, and the system has been found perfectly effective in guns of every size: it involves little circumspection in use, and there is nothing in the gun which can ever require repair. As regards endurance, the pads are almost indestructible, except perhaps from the wear of opening and closing the breech: spare pads are provided with every gun, and if necessary the old one can be easily changed by any one who has seen the operation performed. Some pads have been known to last thousands of rounds, but if the firing is rapid the wad may get softened by heat; in this case the pad should be changed and thrown into cold water for a time, when it will soon be restored to good condition again. Only field guns would be liable to such rapid fire, and the work of changing a pad in a small gun can be performed in a minute. Whatever the size of the piece, guns need never be thrown out of action for want of repair as in the case of cup obturation; but the pads should be carefully handled whenever removed from the gun, for by rough treatment the metal discs might get injured.

Spindle attachment.

In both the systems of obturation described, it is necessary that the pad or the cup should be attached to the breech-screw by means of a spindle, and not rigidly fixed to the face of the block, for after firing each round there is a tendency on the part of the obturator to stick to the sides of the chamber, and render the work of releasing the screw sometimes an operation of difficulty. By means of the spindle attachment the screw is free to turn independently, while its removal from the gun can afterwards be easily effected by a direct pull on the block.

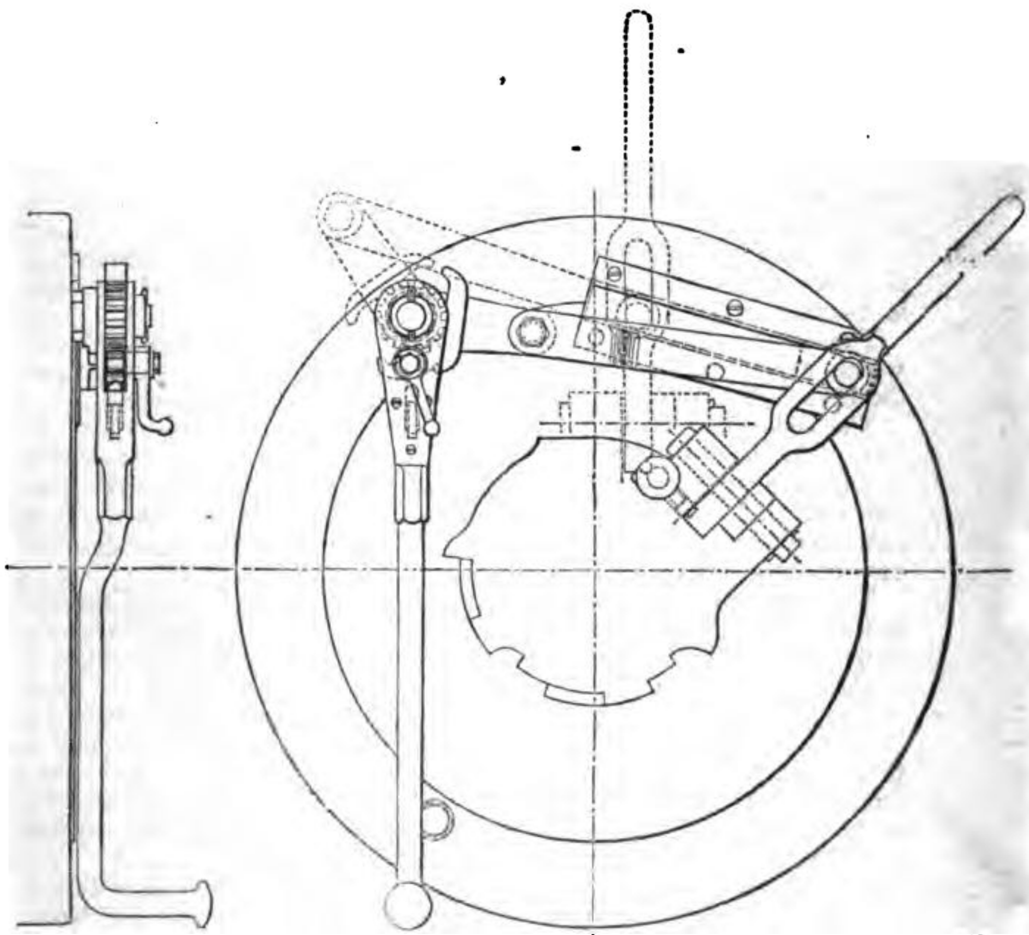
Lever with eccentric and locking arrangement.

With De Bange obturation the lever handle is made to assist in this work, for a cam or eccentric if furnished at the end which is pivoted to the breech-block, by means of which the lever can be made to act as a prise, and so start the movement without any exertion. The eccentric also provides a locking arrangement for the firing position by gearing into a recess in the gun, so that the breech-screw is prevented from shifting on the shock of discharge by the falling of the lever; a

* These rings were originally made of brass, and then of phosphor-bronze, but now they are all made of steel.

tell-tale is also supplied at the time of closing the breech, for it *can* only fall when the breech is properly closed.

APPARATUS FOR ACTUATING BREECH-SCREW.



With 9·2-inch guns and upwards, when hydraulic power is not available, a special power-gaining apparatus is supplied for turning the breech block, and another is to be supplied for withdrawing and pushing it home.

The first is shown above, and consists of a "Stanhope lever" arrangement worked by a pump handle, this engaging in a toothed wheel by means of a double ratchet, which can be thrown over to work either way. The pumping motion of the handle thus transfers a circular motion to one of the arms of the knuckle joint (or Stanhope lever), which arm is pivoted at the centre of the toothed wheel to the face of the breech. The other arm of the joint pivots at one end to the first arm, and at the other end to a block sliding in a rectilinear groove in the face of the breech; this pivot projects so as to engage in a slot in the ordinary lever handle, which is here supplied with a spring knob to keep it raised or permit of its being lowered to bring its cam into play, either in loosening the breech block after firing, or in clamping the breech block before firing in the usual manner.

The pawl or ratchet of the main handle can either be thrown over

CHAP. IV. by hand for reversing the motion, or when properly adjusted is thrown over automatically at the right moment by a curved stop attached to the toothed wheel.

General Remarks.

There are a few points of resemblance which run through the whole class of B.L. guns:

Length. One of their principal features is length, and this is required to suit the large charges of slow-burning powder now used for development of power.

Swell at the muzzle. There is a swell at the muzzle to give strength to a part which is unsupported by adjacent material in front, and most exposed to an enemy's fire.

Bell mouth. The guns are all slightly bell-mouthed; this reduces the length of the bore to a trifling extent, but also reduces the strain as the shot leaves the muzzle.

Chamber. The powder-chamber is greatly enlarged, and with few exceptions, which only occur among the earliest guns, it is cylindrical in form at the breech, to admit a cartridge of the largest diameter possible.

Rifling. The rifling has the M.B. form of groove in all but the 6-inch of ·80 cwt. which has the E.O.C. polygroove. The dimensions of the groove at one time were the same for all natures of guns, but the depth now varies slightly with size. In field guns it is ·04 inch, in the medium natures ·05, and in the heaviest guns ·06 inch. The number of grooves corrresponds with four times the calibre in inches.

Twist. The twist of the rifling in R.G.F. guns increases from a small amount at the breech to a maximum which is generally reached about half-way down the length of the bore, the remainder to the muzzle being uniform at the maximum pitch.

Lines and marks. The lines and letters engraved on these guns are much the same as those found on a muzzle-loading piece, as described in an earlier part of this book, excepting terminal lines for bore and rifling, which are omitted; but the calibre is added upon guns of new type, and this, with the nominal weight and number of the gun, is engraved on the right trunnion, supplying a full designation of the piece.

Guns with cup obturation. The cup obturation will only be found in the first two Marks of 4-inch (viz., 13-cwt. Mark I and 22-cwt. Mark I) and 6-inch 80-pr. and Mark II guns, and in the 32-pr. smooth-bore B.L. gun. This was the method adopted at first, and in some respects, as already explained, it proved to be unsatisfactory. Colonel Maitland accordingly tried the system known by the name of De Bange, which had been used for some years in France, but a doubt seemed to exist about its efficiency, or at any rate as to whether it was applicable to very large guns. Experiments were conducted in the Royal Gun Factory with guns of every calibre, and the results were most satisfactory, so this system was adopted in 1882 for all B.L. guns of new type except those already issued to service; the Elswick cup is restricted to the few natures mentioned above, and will probably be allowed to die out.

Firing arrangements. There are six different systems of firing arrangements in these B.L. guns, which are here briefly described, viz, :—

(1) The copper bush in a radial position as in R.M.L. ordnance but this will be found in the 4-inch of 13 cwt. and 32-pr. S.B. B.L. guns only.

(2) A steel removable bush also radially placed in a vertical plane through the axis for the use of friction tubes of the ordinary pattern. The field guns and the 4-inch Mark I of 22 cwt. are

vented in this manner. The bush can be easily replaced when worn out; it has a mushroom head, which is seated in a spherical recess in the bore, with a copper washer to ensure a close joint.* A wrench is supplied for unscrewing the nut on the top of the bush, and when removed the bush can be pushed down into the gun. Under the nut is a spring washer. The new bush is inserted by hand from below, and a feather will be found in the gun to correspond with a groove in the bush, which prevents it from turning round while being tightened up by the nut.

(3) A percussion firing arrangement of Elswick design, which is applied to the 6-inch guns of 80 cwt. A description of this will be found amongst the details concerning this particular nature of gun.

(4) An axial vent with removable "holder tube" for vent-sealing tubes of "V" pattern, as applied to the 6-inch Mark II. This also will be described with the nature of gun to which it belongs.

(5) An axial vent with a slide and vent-masking hood, made for vent-sealing tubes of "M" pattern, for guns fitted with De Bange obturation. The majority of B.L. guns at first issued had this kind of venting arrangement. For a description and instructions relating to this method of venting, see page 287.

(6) An axial vent with slide and percussion lock for vent-sealing tubes of "P" pattern. This is described with the 4-inch Mark III, and will be applied to all natures, as far as possible, superseding the earlier arrangements.

All three patterns of vent-sealing tubes may be electric, but vents prepared for one nature of tube will not take any of a different description.

Sighting.

B.L. guns are provided with two or three sets of sights; their position is much the same as on R.M.L. ordnance, except that various plans have been adopted for increasing the length of the radius, and the left sights have been removed in some cases to meet a particular system of mounting, and in this case centre hind-sights have been furnished instead.

Tangent-sights.

The tangent scale sights are of two general patterns, viz.: those with bars of square section, and those which are heart-shaped or triangular. The latter are provided with separate metal slips on which are marked the yards scales: these being liable to change with any alteration of charge can be replaced by unscrewing the fixing screw and removing the small retaining piece at the bottom of the bar; the metal slip can then be withdrawn and a new one inserted. This arrangement will not necessitate any new mark of bar being required at any future time should a new charge, &c., be introduced for the gun. Both descriptions are raised in their sockets by a rack on the front face of the bar,† and a movable automatic pinion arrangement in the sight-clamp, which clamps the sight at any elevation. The deflection leaf is traversed by means of a mill-headed screw. In all cases the mark of sight and the gun for which it is made are stamped on the strips and body of bar.

Centre hind sights.

These sights when provided are similar as to body to the R.M.L. sights, being hexagonal; and as to head to the B.L. just described.

* In earlier patterns, the head was saddle-shaped to suit curve of bore.

† The front face is that fronting the muzzle.

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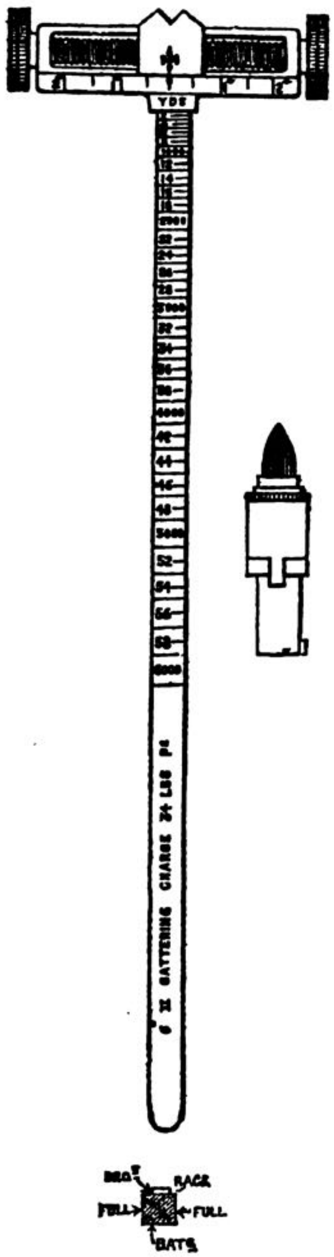
They are necessarily shorter than a side scale, though similarly graduated as far as they go.

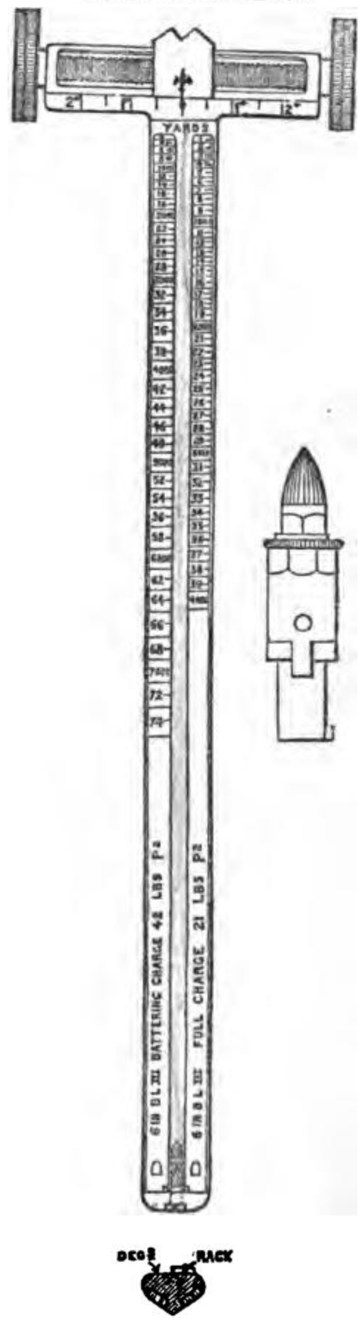
Fore-sights.

The fore-sights, as a general rule, are acorn-shaped, and removable on the drop system with double bayonet joint. A sketch is given on the next page of the sights for the 6-inch Marks II and III, which may be considered typical of the two descriptions of sights applied to nearly all B.L. guns.

6-INCH B.L. MARK II.



6-INCH B.L. MARK III.



The tangent sights with square bar will be found on all the 4-inch and 5-inch B.L. guns, and on the 6-inch Mark II. The heart-shaped bar will be used with the 6-inch Mark III and IV and all heavier natures. There are also some exceptional patterns which will be mentioned with the guns that have been provided with them.

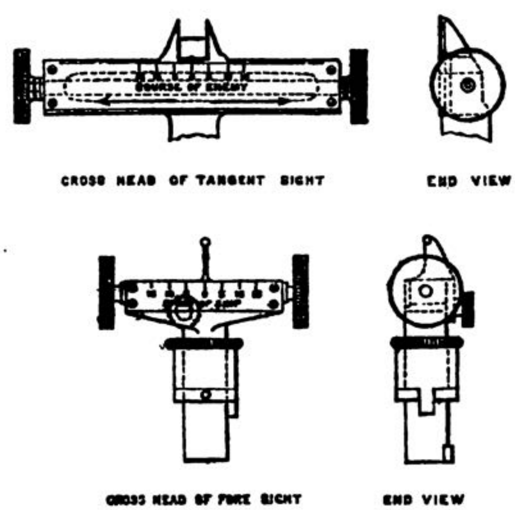
Speed sighting S.S.

For S.S. guns, sights of a different pattern are to be provided, to meet the requirements of firing from a moving platform, having deflection scales marked to enable the proper allowance to be made for direction and speed of the ship and also of the target.

Tangent-sight.

The head is slightly different from the ordinary pattern, the leaf screw is protected from the front, and the leaf takes the form of two standards with a horizontal wire and a small pointer in the centre below. The graduations run in front from zero in the centre to divisions representing 5 knots of speed to right and left up to 15 or 20 knots, and behind is the usual deflection scale reading to 2° either way.

S.S. SIGHTING.



Trunnion-sight.

The trunnion-sight is provided also with deflecting screw and graduations with reference to knots of speed as in the tangent sight; the leaf takes the form of a knife edge surmounted by a knob.

A complete list of sights, fittings, and stores, as issued with each B.L. gun, will be found in a table which is given at the end of this chapter.

We will now proceed to describe all the guns of this class, giving details of their construction, dimensions, and stores. The same order will be followed as in the case of R.M.L. guns, viz.: from the lightest to the heaviest piece, for chronological order cannot be preserved, and it will be convenient to take them according to size.

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12-pr. B.L. Gun. 7 cwt. Mark I.

Calibre, 3 inches. 12 grooves.

(Plate I.)

12-pr. gun. Mark I. § 4877.

This gun is made entirely of steel, and consists of four parts, viz: an A-tube, a jacket, a "C" hoop in front of the trunnions, and a hood (D).

The barrel ceases at the breech end on a level with the face of the screw, which gears into the jacket, so that longitudinal strain is borne by the exterior metal.

The jacket is shrunk on to the A-tube and locked in position by a small turn, which brings a ring of interrupted projections on the inner surface of the jacket in front of a similar row of projections arranged round the A-tube. The hollow spaces are afterwards completely filled up by wedges driven in with a taper corresponding to the slots in the gun. One wedge would be sufficient to key up the jacket, but by driving in wedges all round, continuity of metal is preserved for transmission of strain in a circumferential direction. A small hoop (C) is shrunk on in front of the jacket to secure and cover the wedges, and this also carries the fore-sights. The faces of the trunnions are hollowed out.

The hood (D) is merely a ring screwed on to the end of the jacket to protect the breech-closing mechanism, and supply the means of attachment for the elevating gear.

The breech fittings are of R.G.F. pattern. The breech-screw when withdrawn from the gun is supported on a ring-carrier, which is hinged on the right side of the gun. The lever handle with cam acts in a fourfold capacity, viz.: (1) as lever for turning the screw; (2) as locking-pin in the firing position; (3) as a prise to start the movement in withdrawing the block; and (4) as a tell-tale to show when the breech is properly closed.

The obturation is the De Bange.

The chamber has a length of 11 inches, with a diameter of 3·625. Its capacity is 116·6 cubic inches.

The bore has a length of 28 calibres; the calibre being 3 inches.

The rifling consists of twelve grooves of M.B. section, with a depth of ·04 inch, and the twist increases from 1 in 120 cals. at the breech to 1 in 28 at a point 35·8 inches from the breech, the remainder having an uniform twist of 1 in 28. The lands constitute a stop for the projectile in loading.

The gun is vented radially in the forward position with a steel removable bush.

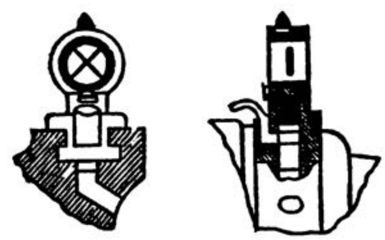
Two sets of sights are provided, one on each side. The tangent bar (Mark I) is a heart-shaped bar graduated on its rear face to 5,000 yards, and with a degree scale on one of its front faces. The bar is provided with a steel crosshead and sliding leaf, by means of which 1½ degrees right or left deflection can be given. The leaf is provided with a notch for rough laying and an eye-hole for fine laying. The tangent bar is adjusted by means of a gun-metal moveable clamp, attached to which is a slow-motion elevating nut, by means of which elevation up to 10 minutes can be given. On one side of the tangent bar a small notch is cut; and a

spring bolt is let into the metal of the sight socket, this bolt fits into the notch when the tangent bar is lowered in the gun in its travelling position.

The fore-sight consists of a gun-metal block, which slides in between two projections in the metal of the gun, and is held in position by a spring bolt. The upper part of the block is provided with an acorn point for rough laying, and a circular window, with cross wires on the inside of it, for fine laying.

FORE-SIGHT.

Scale, ½.



The preponderance of this gun may be found to vary, some of the first made having 40 lbs.; this in guns of more recent manufacture has been reduced to 10 lbs. by shifting the position of the trunnions and elevating eye.

4-inch B.L. Guns.

The manufacture of 25-pr. guns was commenced in 1881. There are two distinct natures, viz.: those of 13 and 22 cwt. The longer gun was designed first, but the Admiralty requested that a shorter and lighter gun might be made of the same calibre for boats and deck guns, so on their approval of the design for a 13-cwt. gun the manufacture was proceeded with at the same time. The designation was afterwards changed from 25-pr. to 4-inch B.L. gun.

4-inch B.L. Gun. 13 *cwt.* *Mark I* (*S.S.*).

(Plate II.)

This gun is made of wrought-iron and steel, consisting of a steel A-tube supported at the breech end by a wrought-iron jacket, with a B-coil of the same material in front of the trunnions. 4-inch 13 cwt. § 4177.

The chamber has a length of 8·3 inches, and diameter of 4·5. Its capacity is 128 cubic inches. It is oval in longitudinal section, being

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contracted at the entrance to 4·12 inches so as to reduce the area for pressure of gas on the breech-block.

The bore of this gun is only 14·8 calibres in length, being specially designed for S.S. as mentioned above.

The obturation is on the cup system with a copper ring in the gun.

The breech-block is received on a gun-metal carrier, which is hinged on the right side, and supplied with automatic spring catches to hold it securely in either the loading or loaded position. A retaining clip on the lever handle engages a catch on the gun when the breech is properly closed.

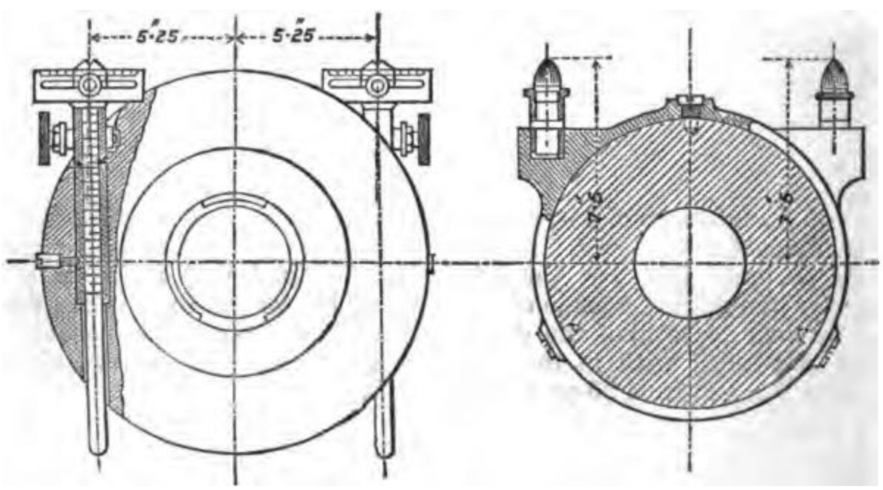
These guns are vented with a copper bush in a radial position 3·8 inches from the face of the cup. They are the only guns in this class which are vented with a fixed copper bush.

The rifling consists of eight grooves, M.B. section ·05 of an inch deep, being just half the number which according to rule there should be in a gun of 4-inch calibre; but this number has proved quite sufficient with this gun.

The twist increases from 1 turn in 116 calibres at the breech to 1 in 35 at 37·92 inches from the breech, the remainder being uniform at 1 in 35.

SIGHTING.

Scale, $\frac{1}{8}$.

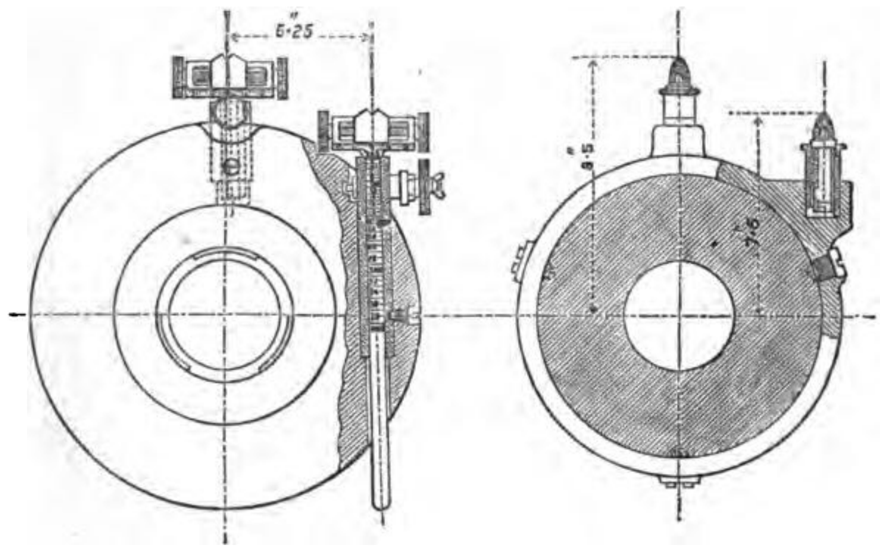


Angle of deflection 1° 40′.

Distance between faces 30 inches.
" " centres 29·787.

These guns were originally provided with two rows of sights, but the left sights have been removed from some pieces to suit the carriage or mounting; in this case central sights have been added instead.

The tangent sights, which are graduated to 12 degrees, and read to divisions of 10 minutes each, have racks on the rear face,



and they are worked by a pinion and clamp. The deflection leaf is worked by a screw, the scale being graduated to 2 degrees right and left, and reading to divisions of 10 minutes each.

The fore-sights are of the drop pattern with steel acorns; they are attached to these guns by a bronze ring, secured by screws to the B-coil.

When the left sights have been removed from the guns on account of method of mounting, and centre sights furnished instead, they are of gun-metal and hexagonal in shape, and on account of being necessarily shorter are only graduated to 5 degrees; deflection scales are provided in the same manner as with the side tangent bars, but a thumbscrew for clamping is provided with the sight socket instead of the movable clamp. C. H. sights.

4-inch B.L. Gun. **22** *cwt. Mark I.*

(Plate II.)

This was originally also designed as a 25-pr. gun, and its construction is exactly the same as that of the 4-inch of 13 cwt., which has just been described. It differs, however, greatly in length, the bore being 25 calibres long. Like the previous gun also, it has the cup obturation. 4-inch 22 cwt. Mark I. § 4196.

The chamber is cylindrical, the diameter being 5·3 inches; but there is a coned portion in front leading into the bore with an easy curve. Its length is 21·4 inches, and capacity 461 cubic inches.

The rifling consists of 16 grooves, M.B. section, with a depth of ·05 inch: the twist increases from 1 turn in 120 calibres at the breech to 1 in 35 at 38·5 inches from the breech, the remainder being uniform at 1 in 35.

The gun has a steel removable vent-bush in the radial position of the form described, p. 279 (foot-note *).

Like the 4-inch of 13 cwt., these guns were sighted at first with side sights, as shown in the sketch; but the left sight has been removed in

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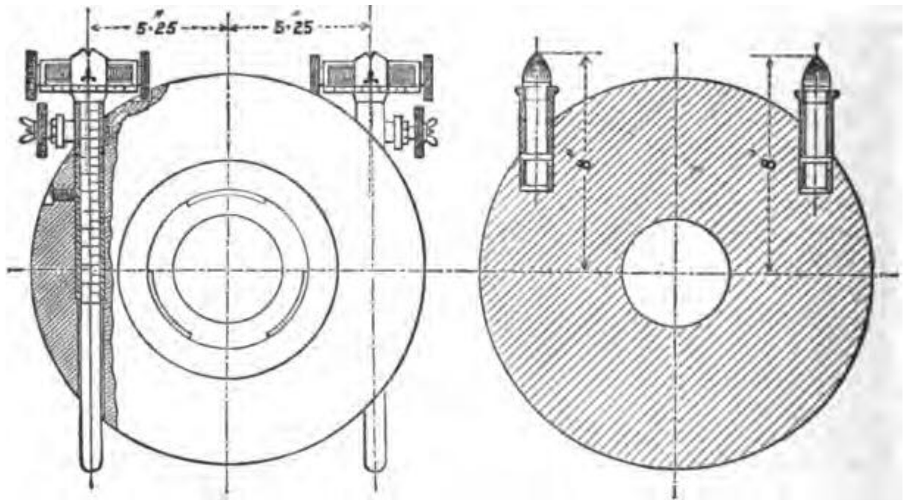
SIGHTING.

Scale, ¼.



Angle of deflection 1° 30′. Distance between faces of tangent and trunnion sights 37.″
„ „ centres „ „ 36·55.″

some cases and central sights given instead: in future they will all be sighted only on the top and right side.

The tangent sights are square in section, and have racks on the rear face; they are worked by a pinion and movable clamp, and a fly-nut has been added to secure the sight at any elevation when required. The deflection leaves are worked by screws with milled heads, the scales being graduated to 2 degrees right and left, reading to 5 minutes.

C.H. sights.

These sights when provided are of the same pattern as those for the 4-inch of 13 cwt.

The fore-sights are of the drop pattern; they are acorn-shaped and of steel.

4-inch B.L. Gun. 22 cwt. Mark II.

(Plate III.)

4-inch 22 cwt. Mark II. § 4688.

The Mark II is composed entirely of steel, and consists of the A-tube supported at the breech with three steel hoops in rear of the trunnions, and one hoop in front. It has also a hood. This gun is 2 calibres longer in the bore than the Mark I, and a little smaller in diameter over the breech. The length of bore is 27 calibres.

The obturation is changed in this Mark from the cup system to the De Bange, and the length of the chamber is reduced to 18·5 inches, so that its capacity is only 417 cubic inches. The pitch of the rifling also is changed, increasing to a maximum of 1 turn in 30 calibres.

Vent-masking hood.

The gun is axially vented through the breech-screw and furnished with a slide and vent-masking hood: the slide is required to support the head of a vent-sealing tube, and the hood to prevent any one from attaching a lanyard until the breech is properly closed. The action of each is automatic when working the gun, and a safety stop has been recently added to make sure that the slide is pushed over the tube after a miss-fire has occurred. This arrangement for safety consists in a screw-stop attached to the gun by a chain; the stop

must be removed after a miss-fire, in order to change the tube in the gun, and it ought to be replaced before firing; its pendant position would be quite sufficient to catch the eye, and remind the gunners if it had not been replaced. The vent-sealing tube should always be inserted with pressure, so as to allow the slide to pass freely over the head, the vent, if necessary, being cleared with a rimer which is supplied for this purpose.

Instructions regarding De Bange obturation and vent-masking hood.

The following instructions have been issued for the care and preservation of guns which are fitted with De Bange obturation, vent-slide, and masking arrangement.

Before closing the breech care should be taken that the vent slide is in proper position, masking the vent; this should be more especially looked to when the vent-sealing tube is inserted while the breech-screw is out of the gun, for if the tube projects, then on closing the breech the inclined plane on the head of the lower fixing screw of the hood (of the gun) will force the slide over the vent, and in doing so it might bend the tube and thus possibly lead to a miss-fire.

The breech fittings should not be kept on the gun, but taken off each day after practice, and occasionally, when not in use, to be thoroughly cleaned and well oiled. A special screw-driver is issued with these fittings. Before attempting removal the breech should be opened, and the carrier secured by its catch.

To remove the handle, take out the two fixing screws that secure this piece to the block, and tapping it gently if necessary with a piece of wood, slide it down until free from its seat.

To remove the obturator, the two keys which wedge up the slide box on either side must be taken out with the hook of the screw-driver; there are holes for the purpose of drawing them out. The slide and slide box in two parts can next be removed, and the obturator is then free to be withdrawn from the front of the breech-screw.

The cam lever for working the breech-screw is hinged by a bolt and keep-pin.

The breech-screw is held in the carrier ring by a stop-bolt on the right side, and by the "clip retaining carrier" on the left. To remove it from the gun the clip must be pressed upwards and the breech-screw pushed slightly forward, when the stop-bolt can be withdrawn; then the breech-screw can be drawn from the carrier towards the rear.

In all cases when the obturator is attached to the breech-screw, the withdrawal of the latter from the carrier should be done by two men, as care is required to keep the clip perfectly clear of the breech-screw before drawing this back; if the block is dropped the pad may be injured.

The carrier ring is attached to the breech of the gun by a hinge-bolt, secured by a screw-stop or keep-pin. By taking out the pin or the stop, and giving a few taps to the bolt underneath with a piece of wood, it can be withdrawn from the gun upwards.

The "clip retaining carrier" is held in a slot in the carrier ring by a fixing screw, or by a bolt with a keep-pin. If on opening the breech the carrier clings to the gun, owing to the clip not working correctly, the latter can be pushed back by a pricker inserted in a hole provided for the purpose on the left side of the breech.

The "latch retaining carrier" which holds the carrier when open is attached to the carrier ring by two fixing screws, or by bolts with keep pins.

The De Bange obturator consists, as already explained, of the axial vent, obturating wad, and metal discs. Grease or tallow mixed with sperm oil should be rubbed occasionally on the wad to keep it in good

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order; the metal discs should be carefully handled to prevent their being bruised: except when taken off for examination they should always be kept on the vent in the gun, as there is a tendency in the pad to swell in an axial direction, which might cause difficulty in inserting the slide box when getting the gun ready for use.

The foregoing instructions will apply also to the 12-pr. guns, but as these are radially vented the breech fittings are not so intricate as in the 4-inch and heavier guns.

4-*inch B.L. Gun.* 22 *cwt.* *Mark III.*

(Plate III.)

4-inch 22 cwt. **Mark** III. § 4878.

The Mark III differs from the previous pattern only in construction and firing arrangement. A solid steel jacket takes the place of the exterior rings, and this portion carries the trunnions, while it also receives the breech-screw; there is a key ring in halves in front of the trunnions to link the jacket to the A-tube; this is covered by a small hoop, which gives nearly the same outline to the gun as the Mark II.

Percussion lock.

These guns are axially vented, and they have been fitted with a slide and percussion lock. The vent is not suited for the "M" or "V" pattern vent-sealing tubes, but is prepared to receive the shorter description, distinguished by the letter "P," which is either of electric or percussion pattern. The slide in this case is more simple than that which is used with vent-sealing tubes of "M" pattern; it works in the side box without any springs, while the action of closing the breech pushes it over the vent, and ensures that the slide shall be in proper position to support the head of the tube. When using a percussion tube it is struck by a hammer which can be cocked either by the thumb or by pulling a lanyard; the other end of the lanyard fires the piece by releasing a trigger: the blow is delivered by the force of a spring, and its intensity does not depend upon the pull of the cord. A safety stop is provided in case the hammer should slip when being cocked by the hand; this consists of a small bar with projections, which intervene to prevent the hammer from hitting the striker. The firing lanyard must always be pulled with a steady arm, for if pulled with a jerk the safety bar might not be withdrawn sufficiently far to prevent its interposing again as in the case of an accidental fall of the hammer. The cocking arrangement is very convenient with heavy guns, for it enables the gunner to "make ready" without mounting upon the platform; and with any nature of piece (large or small) it is useful when firing at an object in motion, for the gun need not be made ready until the object is nearly in line; then a pull with one hand will cock the hammer, and a pull with the other will fire the gun as the object crosses the sights.

With electric vent-sealing tubes of "P" pattern, the wires are led out from the side, so as not to impede the action of the slide, which supports the head of the tube in the usual manner: the percussion lock need not be removed from the gun when using these electric vent-sealing tubes.

4-*inch B.L. Gun.* 26 *cwt.* *Mark IV.*

(Plate III.)

4-inch Mark IV.

Differs from Mark III in construction and weight; the jacket is locked to the A-tube on the "interrupted projection" principle, as

described for the 12-pr., and the B-tube extends further down the chase, necessitating a change in the position of the trunnions to preserve the balance. The internal dimensions are the same as in Mark III. mark iv is hooped up to muzzle

5-inch B.L. Gun. 38 *cwt.* *Mark I.* C

(Plate IV.)

The first Mark of 5-inch calibre is similar in construction to the 4-inch Mark II already described, from which it only differs in dimensions and weight; the breech-screw gears into the barrel, and the latter is reinforced over the seat of the charge with steel hoops and a steel trunnion ring. The details of which are common to both will be given with the 5-inch Mark II. **5-inch Mark I. § 4733.**

The rifling consists of 20 grooves of M.B. section, with a depth of ·05 inch; the twist increases from 1 turn in 120 calibres to 1 in 30 at a point 51·9 inches from the breech, the remainder being uniform at 1 in 30.

These guns are fitted with the slide and vent-masking hood for use with vent-sealing tubes of "M" pattern.

5-inch B.L. Gun. 38 *cwt.* *Mark II.* R

(Plate IV.)

The Mark II differs from the previous gun in construction and firing arrangement, resembling in both these respects the 4-inch Mark III. The breech-screw gears into the jacket, which is linked to the barrel in front by a key ring in halves, over which a small hoop is shrunk to cover and strengthen the joint. **5-inch Mark II. § 4879.**

The percussion lock has been applied to this gun, and the twist of the rifling has been increased to a maximum pitch of 1 turn in 25 calibres.

Both Marks of 5 inches have De Bange obturation with axial vent, and the breech action is exactly the same as on 4-inch guns of corresponding descriptions.

The chamber has a length of 19·3 inches, and diameter of 5·75. Its capacity is 510 cubic inches.

5-inch B.L. Gun. 40 *cwt.* *Mark III.*

(Plate IV.)

Differs from the Mark II in the same way that the 4-inch Mark IV differs from the Mark III, viz., in the extension of the B-tube, altered method of locking jacket to A-tube, and shifting of trunnions, to suit altered conditions of weight. **5-inch Mark III.**

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6-inch B.L. Gun. 81 *cwt.* (80-*pr.*)

(Plate V.)

6-inch 80 cwt. (80-pr.) § 4064. These were the first B.L. guns of new type; they were all manufactured at Elswick, and purchased by Her Majesty's Government in 1880.

The piece is built up of a barrel of steel, over which are shrunk five coils of wrought iron in two layers, and a trunnion ring of forged iron, with steel hoops covering the chase. The breech-screw is brought into gear by a locking turn to the left; in R.G.F. guns this turn is made to the right for convenience of breech fittings and drill; the hinge, however, is in all cases on the right side.

The chamber is oval in section, of a maximum diameter of 7·5 inches, the entrance being 6·5, and this limits the size of the cartridge. The capacity of the chamber is 1,185 cubic inches.

The system of obturation is the Elswick cup and copper ring. The cups are 6·7 inches in diameter, and a proportion of large size are issued for use when the ring is expanded. Brass discs also are necessary to pack up the back of the cup if it should take a set to the curve of breech-block.

The rifling consists of 28 shallow grooves of Elswick type, with lands of about the same width as the grooves. The twist increases from 0 at the breech to 1 turn in 40 cals. at 119 inches from the breech; the remainder being uniform at 1 in 40.

The gun is fitted with a percussion firing arrangement also of Elswick design, which consists of a needle-holder, fitting into the rear part of the breech-block and secured in position against the vent-bolt by means of an interrupted screw-thread. A ~~primer~~ is placed in the front end of the holder, when removed from the gun, and the needle is kept back (but within striking distance) by means of a spiral spring. For mechanical firing a hammer is used which is attached to the breech-screw, and a safety slide with automatic action is fitted on the opposite side, to prevent the hammer from striking the needle until the breech is properly closed; the needle-holder also must be correctly turned in position. For electrical firing the needle must be removed and the wires can then be led through the passage. Omit

The gun is provided with three pairs of sights. The tangent sights, which are graduated to 13°, are of steel with aluminium strips in the sides, having a cross-head of bronze which is fitted with a sliding leaf for deflection capable of being traversed to the extent of 30 minutes either way. The strips are graduated with yards scales; these can be changed with any variation of charge.* The centre-hind-sight is a hexagonal bronze sight graduated to 4°, and provided with a leaf for deflection. The hind-sights fit into sockets placed at an angle of 1° 30′, forming part of the bronze frame which carries the breech mechanism, and secured to the gun by fixing screws.

The fore-sights are of the drop pattern with steel leaves of the hog-backed shape.

§ 4058. The whole of these guns are fitted for broadside sliding carriages. An elevating bracket is attached to the gun by five fixing screws, and it is provided with two steel pivots to afford the necessary attachment to the elevating arc. A few were also prepared with an elevating ring on the chase, for mounting on Albini carriage.

A loading tube is used with this gun to prevent injury to the screw-threads while the shot is being pushed into the bore.

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* The strips have been added to these sights in the R.G.F.

6-inch B.L. Gun. 89 cwt. Mark II.

(Plate V.)

This piece differs from the 6-inch 80 cwt. gun in the following points :— **6-inch Mark II. § 4065.**

(*a*) Construction.
(*b*) Powder-chamber.
(*c*) Rifling.
(*d*) Breech fittings; and
(*e*) Firing arrangement;

besides the essential difference of firing projectiles of 100 instead of 80 lb. weight.

(*a*) The gun is built up of a thick barrel of tempered steel, over which is shrunk a wrought-iron jacket (composed of a coil and trunnion ring welded together). Steel hoops covering the chase, as shown in the Plate, have been added which brings the weight from 81 to 89 cwt.

(*b*) The chamber is cylindrical at the breech end, 8 inches in diameter, decreasing in front with curved form to 6 inches at the commencement of the bore. Being fully open at the breech a short cartridge can be used, made up to the diameter of the chamber, which has a capacity in this case of 1,374 cubic inches.

(*c*) The rifling is of the M.B. description with 24 grooves; the twist increases from one turn to 106·5 cals. at the breech to 1 in 35 at a point 61·75 inches from the breech; the remainder being uniform 1 in 35.

(*d*) The breech-screw has a diameter of 9 inches over the thread, and it locks to the right as in all R.G.F. guns. The breech fittings are entirely different from those on the earlier piece, and not interchangeable with corresponding parts of the 6-inch 81 cwt. gun.

The action of the carrier, which is of bronze, is automatic, the breech screw compressing and releasing the lever and stop. The carrier revolves upon a hinge pin attached to the gun by the hinge-plate, and is held back by a catch when in the loading position, and released again by pressing the button of the retaining clip.

The Elswick cup and copper ring were retained, but the cups are 8·25 inches in diameter; a proportion of "large" size are issued in case the ring should become permanently expanded. Brass discs are also supplied for packing up the back of the cup when required.

A loading tray is supplied (not a tube) to protect the screw-threads, and to raise the projectile to the level of the bore while being rammed home through the chamber.

A wrench in two parts is used to take the breech mechanism apart, and to affix the elevating bracket.

(*e*) The vent passes through the spindle which secures the obturating cup to the face of the breech-screw. A removable tube holder is attached to the rear end of the spindle by an interrupted screw-joint, and this is adapted for "V" pattern vent-sealing tubes either of electric or frictional nature. The tube holder of latest design is fitted with an extractor; a guide-block and groove ensure that it shall be put on the spindle correctly and turned round to the locking position; and there is an arrangement in the tube holder itself for preventing attachment of the lanyard until the tube holder, as well as the breech-screw, is in the proper position for firing.

The guns supplied to H.M.S. "Heroine" and "Satellite" have been altered to percussion lock, and are known as 6-inch Mark II, P. It is probable that the whole of these guns will be so altered.

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The percussion lock in this instance is pressed into the firing position by the act of lowering the cam lever, as in the case of the "Impérieuse" mechanism described in Appendix.

The gun is side and centre-sighted. The hind-sights are raised by rack and pinion motion, and they are also furnished with clamps. The centre hind-sight is a short hexagonal bar of gun-metal; the side-sights are long bars of steel with rack. The deflection leaf is the same in each case, and worked by a screw. The angle of correction for drift is 1° 20′.

The fore-sights are acorn shaped; they are of the "drop" pattern and fit into gun-metal sockets, which in the case of the side-sights are set in brackets screwed on to the side of the gun.

6-*inch B.L. Gun.* 5 *tons.* *Mark III.*

(Plate V.)

6-inch, Mark III. § 4757.

The 6-inch Mark III differs as much from the 6-inch Mark II as the latter does from the previous pattern, and since its first issue a further alteration has taken place, which affects its construction and weight. The points of difference are—

(*a*) Material.
(*b*) Construction.
(*c*) Dimensions and weight.
(*d*) Obturation.
(*e*) Firing arrangement, and
(*f*) Ballistic results.

The gun is made entirely of tough steel, all the portions of which must comply with the same specification before acceptance or use, and all in manufacture are treated and tempered alike.

The barrel or A-tube is much thinner than in the preceding pattern, and it ends at the breech on a level with the face of the screw. A breech-piece is introduced to take the longitudinal stress, and the breech-screw gears into the breech-piece. A B-hoop is shrunk over the chase in continuation of the breech-piece, and as first designed and issued these were linked together by a key-ring in halves. The trunnion ring was next shrunk on with a hook joint, and a small hoop in front covered the key-ring; by this arrangement longitudinal stress is transmitted from the breech-piece to the trunnions, and any movement of the A-tube is prevented.

Three hoops in rear of the trunnions complete the essential part of the gun, but a hood is attached to the extremity of the breech and secured by fixing screws, to protect the lever and fittings. These are of R.G.F. pattern.

The alteration which has been decided upon consists in replacing the key-ring by a trunnion-ring which locks the breech-piece and 1 B-hoop together by "interrupted projections," the chase is hooped to the muzzle, and the 1 C-hoop somewhat extended. This brings the weight (which was originally 89 cwt.), to 5 tons.

The total length in this Mark is increased to 170·7 inches, but owing to an increased length occupied by the breech-closing arrangement there is not the corresponding increase in length of bore. Chamber capacity, 1,364 cubic inches.

The obturation is the De Bange, and the firing arrangement the slide with "Percussion Lock."

The strength of the Mark III is much greater than that of either the 6-inch (80-pr.) or Mark II, which allows of a larger charge being

used; the muzzle energy is increased by nearly one-fourth, as may be seen om the table of ballistics at the end of this chapter; while the perforation of wrought-iron armour at 1,000 yards for the three Marks of gun may be approximately stated at 8½, 9, and 10 inches respectively. CHAP. IV.

6-inch B.L. Gun. 5 tons. Mark IV.

(Plate VI.)

This mark of 6-inch gun has been approved for future manufacture. It assimilates in construction to the latest marks of the natures already described, having a jacket and trunnions in one piece locked to the under layer by the "interrupted projection" method. There is an extra layer of metal, however, in four pieces, viz.: breech-piece, B-tube, and "1 B" and "2 B" hoops; the jacket locks the breech-piece and "B-tube" together, and a short hoop (1 C) covers and secures the wedges. **6-inch, Mark IV.**

The length of the bore is brought up to 26 calibres, but the powder chamber and breech fittings remain as in Mark III.

6-inch B.L. Gun. 5 tons. Mark V.

(Plate VI.)

A certain number of these guns have been purchased from the Elswick Ordnance Company and are of that firm's design and manufacture. Some minor alterations have been made in the breech fittings in the R.G.F. **6-inch, Mark V.**

The construction is entirely of steel (except the breech fittings) and contains three layers of metal. The barrel is in one piece and the breech-screw gears into the breech-piece, which butts against the A-tube and continues in one length to the trunnion-ring, to which it is tied longitudinally by a shoulder. Beyond the breech-piece in the 2nd layer are 4 hoops which extend to the muzzle. The first of these (corresponding to the 1 B-hoop in R.G.F. designs) is attached to the A-tube longitudinally by yellow metal run into a groove in front.

In the third layer a jacket extends in one length over the breech-piece, the rear end butting against shoulders, but the front free except for shrinking grip. The trunnion-ring ties the breech-piece and 1 B-hoop together by shoulders and yellow metal, and a hoop in front covers the 1 B-hoop.

The gun is of considerable length, having a bore of 30·6 calibres.

A bronze frame, attached to the breech by fixing screws, carries the breech mechanism, which is similar to that of the 80-pr., but the firing arrangement has been altered to the percussion lock, similar to the Mark III gun.

The obturation is the E.O.C. cup.

The rifling is of E.O.C. section with twist increasing from 0 to 1 in 30 to near the muzzle.

8-inch B.L. Gun. Marks I & II

The 8-inch were the earliest guns of large size manufactured entirely of steel.

Only two guns of this mark have been made, which are now used for the proof of powder. **8-inch, Mark I.**

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8-inch. Mark II.

The Mark II of this nature is merely a longer gun than the earlier pattern; it was designed at the same time, and as in the case of Mark I only two have been made, which are also used for the proof of gunpowder. The difference in length is 4 calibres or 32 inches, and this adds about 70 f.s. velocity to the shot at the muzzle.

8-*inch B.L. Gun.* 14 *tons.* *Mark III.*

(Plate VII.)

8-inch, Mark III. § 4893.

Considerable changes in design have taken place since the first issue of this nature, and it has been decided to carry out certain alterations in these earlier Marks.

The Mark III, as first issued, was similar to the 6-inch Mark III (already described), and the change to be made is identical with that to be carried out in the 6-inch. At the same time a bronze sheath, formerly used as a counterweight and extended to protect the breech mechanism, will disappear, while the powder chamber will be lengthened to take the larger charge of *Brown* powder used in the Marks V and VI. The weight is changed from 12 to 14 tons. The Plate shows the gun as altered.

The firing arrangement is the percussion lock, similar to the 6-inch III. The carrier is an open one, similar to the 6-inch II, except that the spring catch for retaining the carrier open is attached to the carrier and not to the gun.

Capacity of chamber 3,350 cubic inches. The alterations in powder chamber and charge will somewhat modify the ballistics shown in Tables XIV and XXXV.

The obturation of all the 8-inch is the De Bange.

8-*inch B.L. Gun.* 15 *tons.* *Mark IV.*

(Plate VII.)

8-inch, Mark IV. §

The Mark IV is a reproduction of the Mark II or long gun on the newer style of construction. The dimensions correspond with those of Mark II; the construction corresponds with the latest arrangement of Mark III. There is a further increase of weight, and the trunnions are placed a little more forward.

These guns also are fitted with the percussion lock, and the sights and fittings for the Marks III and IV are interchangeable.

8-*inch B.L. Gun.* 13 *tons.* *Mark V.*
,, ,, 14 *tons.* *Mark VI.*

(Plate VIII.)

8-inch, Marks V and VI.

These guns have been designed and approved for future manufacture. They are of the same general dimensions as the Marks III and IV, but differ from them in all details of manufacture.

They are constructed entirely of steel and consist of the following parts:—An A-tube with "liner" and *a*-tube; a breech-piece and B-tube; a jacket, trunnion-ring, and C-hoop.

The "liner" is a tube inserted in the A-tube with a close mechanical fit *without shrinkage*, and extending about two-thirds of the length of the bore from the breech end, covers the portion where scoring takes place. It bears against shoulders in the A-tube, and is kept in its place by a screw collar in rear.

The *a*-tube is attached to the A-tube by the latter being shrunk on

to it. It also butts against shoulders in the A-tube and is secured from forward movement by a screw collar in front. CHAP. IV.

All liners and a-tubes are secured on the above principles; on referring to them therefore in the higher natures by name only, their respective peculiarities will be understood. It will be found that where an a-tube exists the chase is not hooped its entire length.

The method of uniting the parts together to give longitudinal strength, and to distribute the thrusts of the powder gas on the breech block, and of the projectile on the A-tube, as it is forced along the rifling, may also be discussed somewhat at length in these guns, as representing the principles of other designs.

The layer next outside the A-tube consists of the breech-piece and B-tube. The former takes the breech block and transfers the thrust, causing recoil to the trunnion-ring, by this locking on to it from the front, on the interrupted projection principle. The breech-piece itself is strengthened longitudinally by the jacket (which is shrunk over it) binding it together lengthways by ordinary shoulders in rear, and interrupted projections in front. The tendency to forward motion of the A-tube is checked by the B-tube, which butts against shoulders (or steps) cut on the A-tube, and is in its turn bound to the trunnion ring behind it by interrupted projections. The C-hoop serves the usual purpose of covering the wedges of the last-named joint.

The length of bore in the Mark V gun is 25·6 calibres, and 29·6 calibres in the Mark VI gun. The dimensions and capacities of the two powder chambers are the same, viz., 3,350 cubic inches.

The twist of rifling increases from 1 in 120 to 1 in 35 in a length of 99·7 inches, the remainder uniform.

8-inch B.L. Gun. 12 tons. Mark VII.

(Plate IX.)

These are E.O.C. guns, similar in most respects to the 80-pr. A certain number were purchased for Hong Kong, and sent there as received from Elswick. An alteration in design has since been determined on for this Mark, the chase being hooped with steel as shown in the Plate. **8-inch, Mark VII.**

9·2-inch B.L. Guns.

An experimental gun of this calibre and weight was one of the first B.L. guns manufactured in the Royal Gun Factory. This was built up of wrought iron and steel after the fashion of muzzle-loading guns, the barrel being covered with wrought iron completely from the breech to the muzzle. It was fitted with the Elswick cup obturation. The chamber was oval in longitudinal section at first, and amongst other experiments carried out with this gun one was the trial of a larger breech-screw with the view of adopting cylindrical chambers. This was also the first heavy gun in which the De Bange obturation was tried, and which proved such a thorough success. The system of construction, however, had passed through more than one change before guns of this calibre were manufactured for service. **Experimental gun.**

9·2-inch B.L. Guns $\begin{cases} \text{22 tons. Mark I.} \\ \text{21 tons. Mark II.*} \end{cases}$

The Mark I was designed in 1881 for naval service, and its distinctive feature perhaps was the first introduction of steel coils, as already described for the 8-inch. The gun is built up of a steel **9·2-inch, Marks I and II.** §

* Mark II differs from Mark I in the position of the trunnions only, it being originally a longer gun, but now made the same in length as Mark I.

CHAP. IV. barrel, two steel coils in the centre of different qualities of metal, and steel hoops extending to the muzzle, a breech-piece and C-coil of wrought iron, and a wrought iron jacket. The steel coils were prepared in exactly the same manner as coils of wrought iron, only with much greater care, and they were tempered in oil before use; the higher quality of steel was placed immediately in front of the chamber, and mild steel over the chase. A bronze sheath has been placed on the breech for the same reason as in the 8-inch, but without hood, and a liner has since been added.

The gun has De Bange obturation.

The chamber is enlarged to a diameter of 11 inches, and the length measured from the face of the *tête mobile* to the base of the shot is 44 inches. Its capacity is 4,300 cubic inches, and the form is cylindrical at the breech end. Length of bore 25½ calibres.

The rifling consists of 37 grooves of M.B. section, with a twist which increases from 1 in 118·5 calibres at the commencement to 1 in 35 in a length of 106·6 inches; the remainder being uniform at that pitch.

The vent is axial, and fitted for percussion and electric firing.

A Stanhope lever is added to facilitate the work of opening and closing the breech when performed by hand labour.

9·2-*inch B.L. Gun.* 24 *tons.* *Mark III.*

9·2-inch, Mark III.

The Mark III resembles the previous pattern in very little besides the calibre.

It is built up entirely of steel, cast, forged, and tempered in oil. The A-tube ends opposite the face of the breech-screw, which gears into the breech-piece, in front of which a B-tube is shrunk on and the chase is entirely covered by short hoops. The third layer consists of a jacket, trunnion-ring which locks breech-piece and B-tube together, and a C-hoop covering the wedges.

Only four guns of this nature have been constructed (for the armament of H.M.S. "Impérieuse") and have a breech counterweight, entailed by the particular mounting; the first eighteen guns for L.S. (Mark IV) will be similarly constructed, but without the counterweight.

The length is 310 inches, while the diameter over the breech is 37·5 inches without the sheath. The weight becomes 24 tons.

The diameter of the chamber is 12 inches, and its length is 43·8 inches, and the capacity is 5,000 cubic inches; the total length of the bore is 31·5 calibres. Twist of rifling, 1 in 120 to 1 in 30.

A bronze frame is attached to the breech to carry the breech fittings, the S.S. guns having "controlled carriers." These guns are fitted with a percussion and electric safety firing gear.

The power of this gun far exceeds that of the Marks I and II (see Table of Ballistics at the end of this chapter).

9·2-*inch B.L. Gun.* 23 *tons.* *Mark IV.*

(Plate X.)

9·2-inch, Mark IV.

Guns of this Mark, of which eighteen only have been ordered, have been specially designed for the defence of coaling stations in the colonies.

They are of steel and consist of an A-tube fitted with a "liner" (but no a-tube) which extends for about 10·5 calibres from the base of the projectile; a breech-piece, B-tube, and five hoops extending to the muzzle; also a jacket and trunnion-ring, the latter being locked and wedged over the breech-piece and B-tube and uniting them. A C-hoop is shrunk on in front of the trunnion-ring.

The bore has a length of 31·5 calibres. The total length of the gun is 25 feet 10 inches.

The breech fittings are carried by a bronze frame secured by fixing screws, the carrier being uncontrolled. The gun is fired by the ordinary percussion lock.

9·2-inch B.L. Gun. 22 *tons.* *Mark V.*

(Plate X.)

This Mark of gun has been approved for future manufacture, both for naval and land services. In general construction and dimensions, it resembles the Mark IV of the same nature with the following exceptions:—the chase is not supported the whole of its length, having only a "1 B" tube rather longer than the corresponding one in the Mark IV; this alters the centre of gravity, and the trunnions are 3·5 inches nearer the breech in consequence. The "liner" is carried further towards the muzzle and continued in an a-tube, as in the 8-inch Marks V and VI. There is a bronze frame for the attachment of the breech fittings, and the special mechanism for withdrawing and pushing home the breech-block—termed "controlled carrier." **9·2-inch, Mark V.**

10-inch B.L. Gun. 32 *tons.* *Mark I.**

Guns of this weight were originally intended for a calibre of 10·4 inches; an experimental piece was manufactured in 1880 weighing 26 tons, and shortly afterwards two muzzle-loading guns of about the same dimensions and weight were made for comparison of ballistic effects. The latter proved to be inferior in power, and a number of the breech-loading guns was consequently ordered for service. Their manufacture, however, was delayed while progress was being pushed on with 9·2 and heavier B.L. guns. During this time various modes of construction were adopted in rapid succession, while the question of suitable diameter for projectiles of specified weight, *i.e.*, the best value to be given to the ratio of $\frac{w}{d^3}$, was also undergoing discussion. In the end, a 10-inch calibre was approved for guns of this weight, and the system of construction in force when their manufacture commenced was that just described for the 9·2-inch Mark III. **10-inch, Mark I. §**

It consists of an A-tube, a breech-piece (which receives the breech-screw), a B-tube and a number of hoops in continuation to the muzzle; while the third layer comprises a jacket, trunnion-ring, and small hoop, which are shrunk on with locking arrangement and wedged in position. A bronze frame is also attached to the end of the breech to receive the fittings, with controlled carrier.

The total length is 28½ feet, and the length of bore is 32 calibres.

The chamber has a diameter of 14 inches, with a length of 54; its capacity is 8,370 cubic inches.

The obturation is the De Bange, and the firing arrangement will be the slide with percussion lock.

The rifling consists of 40 grooves ·06 deep, with a twist increasing from 1 turn in 120 calibres to 1 turn in 30.

10-inch B.L. Gun. 29 *tons.* *Mark II.*

(Plate XI)

Has the same internal dimensions as Mark I. It resembles in general construction the 9·2-inch Mark V, with the addition of a hoop **10-inch, Mark II.**

* Guns of this nature are being manufactured at Elswick.

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over the breech marked "1 D." The term "jacket" is here abandoned and the hoop corresponding to it marked "1 C," and the "1 C" of lighter natures re-lettered "2 C."

The breech action will be the same as for Mark I.

12-*inch B.L. Gun.* 47 *tons. Marks I and II.*

(Plate XII.)

12-inch, Marks I and II. § 4891.

This gun is composed of wrought iron and steel, and in construction is similar to the 9·2-inch Mark I, which was designed about the same time.

It consists of a steel barrel with two coils and five hoops of steel, which constitute a layer of this material over the forward part of the core. The breech-piece is made of wrought iron, and so is the C-coil, which forms in continuation of the breech-piece a third layer of metal in the centre, and covers the joint between the 1 B and 2 B-coils. A wrought iron jacket, or D-coil, covers the breech-piece and a portion of the C-coil, and behind this is a gun-metal frame to which the breech fittings, viz., a ring carrier, and a ratchet lever for actuating breech-screw (*vide* p. 277), are attached. The trunnion-ring, of steel, is shrunk and locked by interrupted projections on to the front end of the D-coil, and in front of this to further take the thrust is a ring in segments, dropped into an annular groove in the C-coil, and covered by a thick steel collar.

These guns are fitted with liners, and differ somewhat in internal dimensions from the other Marks of this nature. The total length of bore is 301·75 inches; the length of chamber is 56·5 inches, and diameter 14·75 inches, but the capacity is the same as in the other Marks, viz.: 9,666 cubic inches.

Mark II was exactly the same as Mark I, except in being a trunnionless gun. Eleven of them were made, which have now been converted to L.S., fitted with trunnions, and re-numbered Mark I.

12-*inch B.L. Gun.* 44 *tons. Mark III.*

12-inch, Mark III. § 4925.

The Mark III is a S.S. trunnionless gun built up entirely of steel. It differs from the Mark I in construction, but not much in general dimensions.

In trunnionless guns, three "thrust-collars" are formed on the exterior in lieu of trunnions. These extend half way round on the lower side of the gun beneath the centre of gravity, and are made to seat into grooves in the carriage, to transfer both recoil and twisting strain. Two shallow bands are made nearer the breech to take the connections for guide blocks.

There is no gun-metal plate on these guns, for in the S.S. the breech-block (of the heavier natures) is manipulated entirely by hydraulic arrangements independent of the gun.

The guns of this pattern are being manufactured at Elswick, where the design was prepared as a modification of the R.G.F. designs.

The steel barrel ends on a level with the face of the screw. A breech-piece (which takes the breech-screw) is shrunk over the tube, and yellow metal is run into grooves near the front to assist in securing it to the A-tube. The gun is built up with a large number of hoops of forged steel to the same thickness of metal as the Mark I, the hoops extending to the muzzle, each being shrunk on in succession and

having suitable shoulders to prevent any movement of the several parts of the gun.

The internal dimensions and ballistic powers are the same as in the Marks IV or V.

12-*inch B.L. Gun.* 45 *tons.* *Mark IV.*

The Mark IV is a trunnionless gun of R.G.F. design, made entirely of steel for S.S.: only four are being made, which are intended for the armament of H.M.S. "Edinburgh." 12-inch, Mark IV. § 4926.

It is built up of a larger number of hoops than is now employed in the Mark V, which is simpler; there are 16 pieces in all. Over the A-tube is shrunk the breech-piece and 6 hoops in continuation to the muzzle. The breech-piece (which takes the breech-screw) is tied to the 1 B-hoop by interrupted projections, and the thrust-collar ring butts against shoulders on both of these. There are two layers, of two and three hoops each, over the breech-pieces, which are locked together longitudinally by interrupted projections. Two hoops in front of the thrust-collars complete the design.

The breech mechanism is worked by hydraulic gear attached to the carriage as with the Mark III gun.

In the five Marks of 12-inch guns, the total length is 27 feet 4½ inches, but the length of bore is 301·75 inches in Marks I and II, and 303 in the others.

The chamber in Marks III, IV, and V, has a diameter of 16 inches, with a length of 48, and its capacity is 9,666 cubic inches.

The rifling consists of 48 grooves, ·05 deep, with a twist which increases from 1 turn in 120 calibres to 1 in 35 in a length of 124·525 inches, the remainder being uniform at 1 in 35.

12-*inch B.L. Gun.* 45 *tons.* *Mark V.*

(Plate XIII.)

Will be a trunnionless gun for S.S. like Mark IV, which it is intended to supersede. The internal dimensions are the same, and the outline practically so. The construction, however, differs in the introduction of a liner and *a*-tube in the A-tube, which is consequently not hooped the whole length of the chase, and the short hoops over the breech in Mark IV are replaced by hoops in one length. 12-inch, Mark V.

Two of these guns are in course of manufacture for H.M.S. "Hero."

13·5-*inch B.L. Gun.* 69 *tons.* *Mark I.*

Is made entirely of steel; being a S.S. gun it has no trunnions, but projecting rings are provided in a similar way to those on the 12-inch Marks III, IV, and V. 13·5-inch, Mark I.

As regards construction it has the following features:—There is a liner partly up the bore, but no *a*-tube. The chase is hooped its entire length. There are four layers of metal, the outer of which consists of three hoops over the breech, two of them being locked to the portions underneath.

13·5-*inch B.L. Gun.* 67 *tons.* *Mark II.*

(Plate XIV.)

13·5-inch, Mark II.

This Mark, of R.G.F. design also, has been approved for future manufacture to replace Mark I. In general construction it resembles the 12-inch Mark V.

The general dimensions are the same as the Mark I, but it differs in having an *a*-tube shrunk into the A-tube in continuation of the liner towards the muzzle. The whole of the chase is not hooped, and the hoops over the breech are reduced in number.

16·25-*inch B.L. Gun.* 111 *tons.* *Mark I.*

(Plate XV.)

16·25-inch, Mark I.
§

Guns of this nature are being manufactured at Elswick on designs which have been submitted by the Elswick Ordnance Company.

They consist of 42 parts, viz.: a barrel; a breech-piece and 15 hoops in the second layer of metal; 11 hoops in the third; 8 in the fourth; and 6 in the fifth, extending from the breech to the ribbed belt in the middle, which takes the place of a trunnion ring as these guns are being made for S.S. End-strength is provided by shoulders in the construction, and movement of the barrel is prevented by shrinkage, which in a very long gun can hardly be relaxed over the whole length at the same time; but shrinkage is assisted in this respect by a ring of yellow metal which is run into grooves near the front of the breech-piece, and which is said to have the property of expanding as it cools. The same device is repeated near the front of the belt to prevent any dislocation on firing.

The total length is 43 feet 8 inches, and the length of bore 30 calibres. The chamber has a diameter of 21·125 inches and a length of 83·4. Its capacity is 29,000 cubic inches.

The estimated power of this gun is given in the Table of Ballistics.

32-*pr. Smooth-bore B.L. Gun*, 42 *cwt.*

32-pr. S.B.

There is one B.L. gun which, although it does not belong to the class of ordnance discussed in this chapter, can be most conveniently mentioned here, viz., the 32-pr. smooth-bore B.L. gun.

B.L. gun.
§

This is a conversion from the S.B. cast-iron gun of 42 cwt., with the object of obtaining a convenient piece for firing case shot in the flanks and approaches of permanent works.

The cascable is completely cut off behind the base ring, and the bore is carried through to the breech. The gun is then prepared for a breech-screw on the interrupted-screw plan. The obturation is the Elswick cup and copper ring; this was adopted at first and it has not been thought worth while to change it since only light charges are fired from this gun.

A slightly enlarged chamber is formed by boring out the metal in front of the obturating cup to a distance of 4·1 inches; the shoulder so made becomes a stop for the case-shot in loading.

The gun is radially vented with a copper bush.

These guns will generally be fired "point-blank," the effect being sufficiently great up to 500 yards without any elevation. They are

therefore provided with a fore-sight only, which is similar to the fore-sight on a S.B. cast-iron gun, and the line in laying is taken through a groove cut on the breech.

This nature of piece can be fired with very great ease and rapidity, giving little recoil, so that it is specially suited for use behind mantlets or ports of small size, the detachment being thus kept under cover.

The few stores required are similar to those which are used with the 4-inch B.L. gun of 13 cwt.; it is therefore convenient to place them in the same table, which will be found at the end of the chapter. (See Table XXXV, p. 306.)

OBDURATION
BREECH FERMATURE

CHAP IV.

TABLE XXXII.

Showing the Dimensions, Rifling, &c., of B.L. Guns.

Nature.	Mark.	Weight.	Calibre.	Obturation.	Length. Total.		Length. Bore.		Length. Rifling.	Chamber. Length.	Chamber. Diameter.	Chamber. Capacity.	Rifling. System.	Rifling. Twist.*	Rifling. No. of Grooves.	Remarks.
		cwt.	ins.		ft.	ins.	ins.	cals.	ins.	ins.	ins.	c. i.				
12-pr.	I	7	3	De Bange	7	8·35	84·0	28·0	71·6	11·0	3·625	116·6	M.B.	I. From 1 in 120 to 1 in 28 at 35·8 ins. from breech.	12	
4-inch	I	13	—	Copper ring and cup	5	6	59·25	14·8	49·315	8·3	4·5	123·0	”	I. From 1 in 116 to 1 in 35 at 37·92 ins. from breech.	8	
4-inch ...	I	22	—	”	8	10·75	100·0	25·0	76·87	21·4	5·3	461	”	I. From 1 in 120 to 1 in 35 at 38·5 ins. from breech.	16	
	II	23	—	De Bange	10	0	108·0	27·0	87·77	18·5	5·3	417	”	I. From 1 in 120 to 1 in 30 at 44 ins. from breech.	16	
	III	23	—	”	10	0	108·0	27·0	87·77	18·5	5·3	417	”	” ”	16	
	IV	26	—	”	10	0	108·0	27·0	87·77	18·5	5·3	417	”	” ”	16	
5-inch ...	I	38	—	”	11	7·5	125·35	25·1	104·3	19·0	5·75	510	”	I. From 1 in 117 to 1 in 30 at 51·9 ins. from breech.	20	
	II	38	—	”	11	7·5	125·35	25·1	104·3	19·0	5·75	510	”	I. From 1 in 120 to 1 in 25 at 52·15 ins. from breech.	20	
	III	40	—	”	11	7·15	125·0	25·0	104·3	19·0	5·75	510	”	” ”	20	
6-inch ...	...	81	—	Copper ring and cup	13	4·6	153·2	25·5	123·02	27·8	7·5	1,185	E.O.C. Poly-groove.	I. From 0 to 1 in 40 at 119 ins. from breech.	28	E.O.C. gun.
	II	89	—	”	12	9·2	144·0	24·0	102·875	26·75	8·0	1,374	M.B.	I. From 1 in 106·5 to 1 in 35 at 61·75 ins. from breech.	24	
	III	5 tons	—	De Bange	14	2·7	153·2	25·5	124·075	26·75	8·0	1,364	”	I. From 1 in 120 to 1 in 35 at 65·125 ins. from breech.	24	
	IV	5 tons	—	”	14	5·5	156·0	26·0	126·875	26·75	8·0	1,364	”	” ”	24	
8-inch ...	III	14	—	”	18	6·5	204·9	25·6	167·4	38·0	10·5	3,350	”	I. From 1 in 99 to 1 in 35 at 95·6 ins. from breech.	32	
	IV	15	—	”	21	2·5	236·9	29·6	199·4	38·0	10·5	3,350	”	” ”	32	
	V	13	—	”	18	6·5	204·9	25·6	163·9	38·0	10·5	3,350	”	I. From 1 in 120 to 1 in 35 at 99·7 ins. from breech.	32	
	VI	14	—	”	21	2·5	236·9	29·6	195·9	38·0	10·5	3,350	”	” ”	32	

2-inch	I	22	—	"	21	3·8	235·63	25·6	187·73	44·0	11·0	4,300	"	I. From 1 in 118·5 to 1 in 35 at 106·6 ins. from breech.	37	
	II	21	—	"	21	3·8	235·63	25·6	187·73	44·0	11·0	4,300	"	" "	37	
	III	24	—	"	25	10	289·8	31·5	243·2	43·8	12·0	5,000	"	I. From 1 in 120 to 1 in 30 at 121·6 ins. from breech	37	
	IV	23	—	"	25	10	289·8	31·5	243·2	43·0	12·0	5,000	"	" "	37	
	V	22	—	"	25	10	289·8	31·5	243·2	43·0	12·0	5,000	"	" "	37	
10-inch	I	32	—	"	28	6·4	320·0	32·0	263·0	54·0	14·0	8,370	"	I. From 1 in 120 to 1 in 30 at 131·5 ins. from breech.	40	
	II	29	—	"	28	6·4	320·0	32·0	263·0	54·0	14·0	8,370	"	" "	40	
12-inch	I & II	47	—	"	27	4·5	301·75	25·1	240·75	56·5	14·75	9,666	"	I. From 1 in 103 to 1 in 35 at 116·225 ins. from breech	48	
	III	44	—	"	27	4·5	303·0	25·25	247·6	49·0	16·0	9,666	"	I. From 1 in 120 to 1 in 35 at 124·525 ins. from breech	48	E.O.C. gun.
	IV	45	—	"	27	4·5	303·0	25·25	247·6	49·0	16·0	9,666	"	" "	48	Trunnionless.
	V	45	—	"	27	4·5	303·0	25·25	247·6	48·0	16·0	9,666	"	" "	48	"
13·5-inch	I	69	—	"	36	1	405·0	30·0	333·4	66·5	18·0	17,100	"	I. From 1 in 120 to 1 in 30 at 166·7 ins. from breech.	—	"
	II	[illegible]	—	"	36	1	405·0	30·0	333·4	66·5	18·0	17,100	"	" "		
16·25-inch ...	I	111	—	"	43	8	487·5	30·0	—	83·4	21·125	29,000	E.O.C.	— —	—	E.O.C. gun, trunnionless.

* "From breech" means from breech end of rifling, where it commences at its full depth.

CHAP. IV.

TABLE XXXIII.

Showing the Nature of Tangent Sights for B.L. Guns.

Nature of Gun.	Angle of correction for drift.	Radius distance.	Latest mark of sight.	Graduations.					Deflection, right and left.	Reference.	Remarks.
				Degrees.	Range Scale.			Fuze.			
					Charge.	Projectile.	Yards.				
	° '	"			lb.				° '	§	
12-pr. Tangent sight	1·30	35·0	I	12	4P	CS	5,000	34	1·30	—	Three-sided.
4-inch, 13 cwt. Tangent sight	1·40	30·0	III	12	3·25	CS	4,000	—	2·0	4,177	Square bar.
4-inch, 22 cwt., Mark I. Tangent sight	1·30	37·0	II	12	12·0	—	4,500	30	2·0	4,196	Ditto.
4-inch, 22 cwt., Marks II, III, and IV. Tangent sight	1·30	37·0	II	20	12·0	—	7,700	—	2·0	—	Ditto.
5-inch, Marks I, II, and III. Tangent sight	1·30	37·0	II	20	16·0	—	8,700	—	2·0	—	Ditto.
6-inch, 80 cwt. (80 pr.) Tangent sight	1·30	52·0	II	13	34·0	—	5,000	—	1·30	4,054	Rectangular, with brass slips.
Centre-hind-sight ...	1·30	52·0	I	4	34·0	—	3,400	—	—	—	
6-inch, Mark II. Tangent sight	1·20	54·2	II	12	34·0	—	6,000	—	2·0	4,065	Square bar.
Centre-hind-sight ...	1·20	54·5	I	4	34·0	—	3,000	—	2·0	4,065	
6-inch, Marks III and IV. Tangent sight	1·20	49·5	II	12	42·0	—	7,500	—	2·0	—	Three-sided.
8-inch, Mark III. Tangent sight	1·40	77·5	I	12	10·0	—	8,000	—	2·0	—	Ditto.
8-inch, Mark IV. Tangent sight	1·40	77·5	I	12	10·0	—	8,000	—	2·0	—	Ditto.
9·2 inch, Mark I. Tangent sight	1·40	77·5	I	12	16·0	—	—	—	2·0	—	Ditto.
9·2-inch, Mark II. Tangent sight	1·40	77·5	I	12	16·0	—	—	—	—	—	Ditto.
9·2-inch Marks III and IV. Tangent sight	1·40	60·0	I	15	17·5	—	—	—	—	—	Ditto.
10-inch. Tangent sight	1·30	77·5	I	15	25·0	—	—	—	—	—	Ditto.
12-inch, Marks I and III. Tangent sight	1·30	77·5	I	12	29·5	—	—	—	2·0	—	Ditto.
12-inch, Marks II, IV, and V. 13·5-inch. 16·25-inch.	These *guns* will not be sighted, as they will be mounted in turrets.										

TABLE XXXIV.

SHOWING THE SIGHTS, STORES, AND FITTINGS ISSUED WITH B.L. GUNS.

TABLE

SHOWING THE SIGHTS, STORES, AND FITTINGS

Description of Stores.	Nature. 12-pr.	4-inch. 13-cwt.	4-inch. 22 cwt. I	4-inch. 22 cwt. II	4-inch. 22 cwt. III	5-inch. I	5-inch. II	5-inch. III	6-inch. 80-pr.	6-inch. II	6-inch. III	6-inch. IV	6-inch. V	
Bands, elevating (with two pivots), &c.	—	—	—	1	I	—	—	—	—	1	1	1	1	1
Bolts, elevating (with keep-pin)	1	—	—	—	—	—	—	—	—	—	—	—	—	2
Bolts, securing...	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Bolts, stop (breech-screw)	1	—	—	1	1	1	1	1	—	—	1	1	—	4
Bolts, vent (with nut, spring, and washer) ...	1	—	1*	—	—	—	—	—	1	—	—	—	—	5
Boxes slide, in two parts, with two springs	—	—	—	1	—	1	—	—	—	—	—	—	—	6
Boxes slide, in two parts, with lanyard bolt, nut, and spiral spring...	—	—	—	—	1	—	1	1	—	—	1	1	1	7
Brackets, elevating, left	—	—	—	—	—	1	1	1	1	1	—	—	—	8
Brackets, elevating, right	—	—	—	—	—	—	—	—	—	—	—	—	—	9
Brackets, retaining, carrier (open), with two screws	—	—	—	—	—	—	—	—	1	—	—	—	1	0
Brackets, fore sight	—	—	—	—	—	—	—	—	—	2	—	—	—	1
Brackets, tangent sight	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Carriers, with hinge bolt, &c.	—	1	1	—	—	—	—	—	1	1	—	—	1	3
Clamps, tangent sight, automatic, A	—	2	2	2	2	2	2	2	—	2	—	—	—	4
Clamps, tangent sight, automatic, B	—	—	—	—	—	—	—	—	—	—	2	2	—	5
Clamps, tangent sight, automatic, C	—	—	—	—	—	—	—	—	—	—	—	—	—	6
Clamps, tangent sight (with elevating nut, screw clamping and keep-pin)	2	—	—	—	—	—	—	—	2	—	—	—	1	7
Clip, head, axial...	1	—	—	—	—	—	—	—	—	—	—	—	—	8
Clip, retaining carrier	—	1	1	—	—	—	—	—	—	1	—	—	—	9
Cups, obturating, large	—	1	1	—	—	—	—	—	2	1	—	—	2	0
Cups, obturating, small	—	2	2	—	—	—	—	—	2	2	—	—	2	1
Discs, cup (brass)	—	3	3	—	—	—	—	—	3	3	—	—	3	2
Discs, bolt, vent (brass)	—	—	—	—	—	—	—	—	6	—	—	—	—	3
Discs, pad, obturating, adjusting (steel)	2	—	—	2	2	2	2	2	—	—	2	2	—	4
Discs, " " protecting (tin, front and rear)	1	—	—	1	1	1	1	1	—	—	1	1	—	5
Ejector, electric	—	—	—	—	—	—	—	—	—	—	—	—	—	6
Extractors, tube, M...	—	—	—	1	—	1	—	—	—	—	—	—	—	7
Extractors, tube, P	—	-	—	—	1	—	1	1	—	—	1	1	—	8
Extractors, tube, P special	—	—	—	—	1	—	1	1	—	—	1	1	—	9
Frames, roller	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Heads, axial (steel)	1	—	—	—	—	—	—	—	—	—	—	—	—	1
Holders, tube (with extractor, &c.)	—	—	—	—	—	—	—	—	—	1	—	—	—	2
Holders, tube, electrical	—	—	—	—	—	—	—	—	1	—	—	—	—	3
Holders, tube, mechanical (with needle)	—	—	—	—	—	—	—	—	1	—	—	—	—	4
Indicator, safety, with chain and screw	—	—	—	1	—	1	—	—	—	—	—	—	—	5
Lanyard guide	—	1	1	—	—	—	—	—	—	—	—	—	—	6
Levers, ratchet, breech-screw	—	—	—	—	—	—	—	—	—	—	—	—	—	7
Levers, releasing, breech-screw (wood)	—	1	1	—	—	—	—	—	1	1	—	—	—	8
Lock, percussion	—	—	—	—	1	—	1	1	—	—	1	1	1	9
Locks, percussion, A	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Masks, vent, axial	—	—	1	—	—	1	—	—	—	—	—	—	—	1
Pads, obturating	1	—	—	1	1	1	1	1	—	—	1	1	—	2
Plates, elevating (with pivot "C" and keep-pin, and two fixing screws) left, lower	—	1	—	—	—	—	—	—	—	—	—	—	—	3
Plates, elevating (with pivot "C" and keep-pin, and two fixing screws) left, upper	—	1	—	—	—	—	—	—	—	—	—	—	—	4
Pins, friction tube	—	1	1	—	—	—	—	—	—	—	—	—	—	5
Plates, hinge	—	1	1	—	—	—	—	—	—	1	—	—	—	6
Prickers, vent, bolt	1	—	—	—	—	—	—	—	—	—	—	—	—	7
Rimers, vent axial	—	—	—	1	1	1	1	1	—	1	1	1	1	8
Rings, carrier	1	—	—	1	1	1	1	1	—	—	1	1	—	9
Rings, obturating	—	1	1	—	—	—	—	—	1	1	—	—	1	0
Rings, sight, centre, right	—	1	—	—	—	—	—	—	—	—	—	—	—	1
Rings, sight, left, right	—	1	—	—	—	—	—	—	—	—	—	—	—	2
Screws, breech with cam lever, &c.	1	—	—	1	1	1	1	1	—	—	1	1	1	3
Screws, breech with lever and clip, &c.	—	1	1	—	—	—	—	—	1	1	—	—	—	4
Screws, fixing, bracket, elevating	—	—	—	—	—	2	2	2	5	5	—	—	—	5
Screws, fixing, bracket, fore sight	—	—	—	—	—	—	—	—	—	6	—	—	—	6
Screws, fixing, cover, securing bolt	—	—	—	—	—	—	—	—	—	—	—	—	—	7
Screws, fixing, plate, elevating	—	4	—	—	—	—	—	—	—	—	—	—	—	8
Screws, preserving, bracket, elevating ...	—	—	—	—	—	2	2	2	5	5	—	—	—	9
Screws, preserving, bracket, fore sight ...	—	—	—	—	—	—	—	—	—	6	—	—	—	0
Screws, preserving, bracket, retaining carrier	—	—	—	—	—	—	—	—	2	—	—	—	—	1
Screws, preserving, plate, elevating	—	4	—	—	—	—	—	—	—	—	—	—	—	2
Screws, preserving, pin, friction tube	—	2	2	—	—	—	—	—	—	—	—	—	—	3
Screws, preserving, lanyard guide	—	1	1	—	—	—	—	—	—	—	—	—	—	4

* Without spring.

† Special 1½-inch.

XXXIV.

ISSUED WITH B.L. GUNS.

	Nature.																			
	8-inch.				9·2-inch.				10-inch.		12-inch.					13·5-inch.		16·25-inch.		32-pr. S.B. of 42 cwt.
	III	IV	V	VI	I	II	III	IV	I	II	I	II	III	IV	V	I	II	I	II	
1	1	1	—	—	1	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—	—	1	—	1	1	—	—	—	—	—
4	—	—	—	—	—	—	1	1	1	1	1	—	1	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	1	1	—	—	1	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—
8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
3	1	1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	2	2	—	—	2	2	3	—	—	—	2	—	2	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	2	2	—	—	2	2	2	2	2	2	2	2	2	2	2	—	—	—	—	—
5	1	1	—	—	1	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—
6	—	—	—	—	1	1	1	—	—	—	—	1	—	1	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	1	1	—	—	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—	—
9	1	1	—	—	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	—	—	—	—	1	1	1	1	1	1	1	—	1	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
9	1	1	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—
0	—	—	—	—	1	1	1	1	1	1	—	1	—	1	1	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	1	1	—	—	1	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	1	1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	1	1	—	—	1	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—
9	—	—	—	—	—	—	*1	*1	*1	*1	1	—	1	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	1	1	—	—	1	1	1	1	1	1	1	—	1	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
5	—	—	—	—	—	—	—	—	—	—	6	—	6	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—	—	—	—	4	—	4	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—	6	—	6	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* With gear controlling breech screw.

TABLE XXXIV

Description of Stores.	Nature. 12-pr.	4-inch. 13-cwt.	4-inch. 22-cwt. I	4-inch. 22-cwt. II	4-inch. 22-cwt. III	5-inch. I	5-inch. II	5-inch. III	6-inch. 80-pr.	6-inch. II	6-inch. III	6-inch. IV	6-inch. V	
Sights, B.L., fore, A	—	1	—	—	—	—	—	—	—	1	—	—	—	1
Sights, B.L., fore, B	—	—	—	—	—	—	—	—	—	—	1	1	—	2
Sights, B.L., fore, C	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Sights, B.L., fore, E	—	—	1(a)	1	1	1	1	1	—	—	—	—	—	4
Sights, B.L., fore, (with stud retaining and spiral spring, bush with sight wires), &c.	2	—	—	—	—	—	—	—	—	—	—	—	—	5
Sights, B.L., hind, centre	—	1	1	—	—	—	—	—	1	1	—	—	—	6
Sights, B.L., speed, fore	—	1	1	2	2	2	2	2	2	2	2	1	—	7
Sights, B.L., speed, tangent	—	1	1	2	2	2	2	2	2	2	2	1	—	8
Sights, B.L., tangent	2	—	—	—	—	—	—	—	—	—	—	1	1	9
Sights, B.L., centre fore	—	—	1	—	—	—	—	—	1	—	—	—	—	0
Sockets, sight, centre hind	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Studs, stop (clip, retaining breech screw)	—	1	1	—	—	—	—	—	1	1	—	—	—	2
Studs, catch (apparatus withdrawing)	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Studs, catch, No. 1 (retaining carrier, closed) ...	—	—	—	—	—	—	—	—	—	—	—	—	—	4
Studs, catch, No. 2 (,, ,, open) ...	—	—	—	—	—	—	—	—	—	—	—	—	—	5
Studs, for tray, loading	—	—	—	—	—	—	—	—	—	—	—	—	—	6
Studs, catch (retaining carrier, closed)	—	1	1	—	—	—	—	—	—	1	—	—	—	7
Trays, cartridge	—	—	—	—	—	—	—	—	—	—	—	—	1	8
Trays, shot	—	—	—	—	—	—	—	—	—	1	1	1	1	9
Tube, loading	—	—	—	—	—	—	—	—	1	—	—	—	—	0
Vents, axial, with spring, &c.	—	—	—	—	—	—	—	—	—	—	1	1	—	1
Vents, axial, without spring...	—	—	—	1	1	1	1	1	—	1	—	—	1	2
Wrenches, bracket, elevating	—	—	—	—	—	—	—	—	1	—	—	—	—	3
Wrenches, breech action (percussion lock) ...	—	—	—	—	1	—	1	1	—	—	1	1	1	4
Wrenches, ,, A	—	1	1	—	—	—	—	—	—	—	—	—	—	5
Wrenches, ,, B	—	1	1	—	—	—	—	—	—	—	—	—	—	6
Wrenches, bolt, vent, 12-pr....	1	—	—	—	—	—	—	—	—	—	—	—	—	7
Wrenches, extracting	—	—	—	1	—	1	—	—	—	—	—	—	—	8
Wrenches, nut, vent	1	—	—	—	—	—	—	—	—	—	1	1	—	9
Wrenches, pivot, No. 4	—	1	1	1	1	1	1	1	—	1	1	1	—	0
Wrenches, set of 4 (a, b, c, d)	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Wrenches, stud No. 1 (in 6 parts)	—	—	—	—	—	—	—	—	—	—	—	—	—	2

(a) Right side only. The

—continued.

	Nature.																			
	8-inch.				9·2-inch.				10-inch.		12-inch.					13·5-inch.		16·25-inch.		32-pr. S.B. of 42 cwt.
	III	IV	V	VI	I	II	III	IV	I	II	I	II	III	IV	V	I	II	I	II	
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	1	1	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	2	2	—	—	2	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—
8	2	2	—	—	2	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—	2	—	2	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
3	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—
4	1	1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	1	1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
8	1	1	—	—	1	1	1	1	1	1	1	—	1	—	—	—	—	—	—	—
9	1	1	—	—	1	1	1	1	1	1	1	—	1	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	1	1	—	—	1	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	1	1	—	—	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	1	1	—	—	1	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—
0	1	1	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	1	1	1	1	1	1	1	—	1	—	—	—	—	—	—	—

centre is special.

TABLE XXXV.

TABLE OF BALLISTICS FOR B.L. GUNS.

Gun.	Mark.	Charge.		Projectile.	Muzzle.		Perforation of wrought-iron armour-plate at 1000 yards.	Remarks.
		Weight.	Powder.		Velocity.	Energy.		
		lb.		lb.	f. s.	f.t.	inches.	
12-pr.	I	4	S.P.	12·5	1705	252	3·7	
4-inch, 13 cwt.	I	3·25	R.L.G.[2]	25	1180	241	3·4	
4-inch, 22 cwt.	I	12	S.P.	25	1790	553	5·0	
4-inch	II, III, & IV	12	S.P.	25	1900	626	5·5	
5-inch	I, II, & III	16	S.P.	50	1780	1098	6·9	
6-inch (80-pr.)	—	34	S.P.	80	1880	1963	8·5	
6-inch	II	34	P[2]	100	1660	1911	8·8	
	III	42	P[2]	100	1850	2378	9·9	
8-inch	III	100	Prism[1], black	210	1960	5590	13·4	
	IV	100	Do.	210	2030	5973	14·0	
9·2-inch	I & II	160†	Prism[1], brown	380	1845	8969	16·3	
	III, IV, & V	175	Do.	380	2050	11073	18·5	
10-inch	I & II	250	Do.	500	2100*	15313*	21·1*	
12-inch	I to V	295	Do.	714	1892	17723	20·4	
13·5-inch	I & II	520	Do.	1250	1960*	33810*	27·3*	
16·25-inch	I	900	C[2]	1800	2020*	50924*	30·6*	

* Estimated.

† This will probably be altered to 140 lb.

R

PART IV.

CHAPTER I.

EXAMINATION OF ORDNANCE.

General regulations.—Provisional and final condemnation.—Periods for examination.—Ordnance on artillery charge at home and abroad.—Guns in charge of the Royal Navy.—Reventing stations.—Inspections at sea.—Ordnance used by the Royal Marine Artillery, Naval Reserve, &c.—Impressions before and after reventing.—Inquiry after accident.—Memorandum of examination.—Nature of periodical inspections.—Examination of vents.—Limits of through gauge.—Erosion in the bore.—Limits of wear for reventing with cone or through bush.—Fissures and cracks.—Removable vents.—Examination of bore.—Preparation of the gun.—Use of potash.—Lamp and searchers.—Instuments for taking gutta-percha impressions.—Extemporary arrangements.—Method of preparing the gutta-percha.—Whole length impressions of the bore.—Rules for indicating the position of defects.—Labels.—Description of defects which may be found in a gun and their relative importance.—Further firing before sentence.—Examination of B.L. fittings.—6-inch 80-pr. gun.—Removal of the cup.—6-inch Mark II.—B.L. guns generally.—R.B.L. guns.—Exterior of ordnance.—Importance of general knowledge to all officers using the guns.

Regulations. THE following regulations have been issued from time to time on the subject of examination of ordnance.

Final condemnation. Great experience is required before an examiner is competent to judge of the various defects and conditions of all the different natures of ordnance used in the service; *final* condemnation therefore will be pronounced only by the Superintendent of the Royal Gun Factory.

Provisional condemnation. In all cases, however, where there are sufficiently serious defects, or if there be any doubt as to the serviceable state of the piece, it may be *provisionally* condemned, and if necessary exchanged, pending the decision of the Superintendent of the Royal Gun Factory.

Period of examination. All ordnance will, as far as possible, be examined regularly after a certain number of rounds, as set forth in the following table, and practice from such ordnance should be discontinued until the examination has been carried out.

CHAP. I.

PERIODS OF EXAMINATION.

Periods of examination: service ordnance.

Natures.				No. of rounds with projectiles.
Rifled ordnance	M.L.	35 tons, and all heavier natures ..	after	32
		12-inch (of 25 tons), 11-inch, 10 inch, and 9 in.	"	50
		8-inch, 7-inch, 6·6-inch, 64, and 13-pr.	"	100
		6·3-inch, 40-pr. and under	"	150
	R.B.L.	7-inch	"	100
		40 pr. and under	"	150
	B.L.	12-inch and upwards	"	32
		below 12-inch to 8-inch	"	50
		below 8-inch to 4-inch of 22 cwt. ..	"	100
		below 4 inch 22 cwt.	"	150
S.B. ordnance		Firing 10-lb. charges and upwards..	"	100
		Under 10-lb. charge	"	200

For purposes of computation four rounds of blank charges may be considered equal to one round with projectile.

Experimental guns. These regulations, however, will not apply to experimental guns, or to service guns used for experimental work, which will be examined according to special orders.

Blank charges. All ordnance used for saluting or blank charges only, will also be examined after four times the number of rounds laid down for that nature of gun when fired with projectiles. This rule will apply to all ordnance in charge of corporations and public bodies in the United Kingdom, as well as to those on artillery charge.

Special cases. In all cases, however, should there be any appearance of fissures about the vent, or defects likely to develop with firing, guns will be examined more frequently, at the discretion of the Examining Officer; but in the case of guns on board a sea-going ship they should if possible be made serviceable, rather than be sentenced for a limited series of rounds, a course which should be avoided where practicable.

Ordnance in Royal Artillery charge at home. For home service the following arrangements will be carried out for ordnance in charge of the Royal Artillery.

As soon as a piece has fired the number of rounds since previous examination as laid down in the foregoing schedule, a notification of the circumstance will be sent, in the case of rifled ordnance, to the Director of Artillery and Stores, in the case of smooth-bore ordnance to the Superintendent of the Royal Gun Factory, on Army Form G 875 (late W.O. Form 1473), by the Officer Commanding the District, and practice from this piece will cease until its condition has been reported upon. Gutta-percha impressions should, if possible, accompany the report, properly labelled, as the Director of Artillery and Stores may, after their inspection, be able to allow of continuance of practice without waiting for the next official inspection. Once a year, or more often if necessary, an examiner and an artificer from the Royal Gun Factory will visit each district and examine those pieces which have fired the prescribed number of rounds, and perform such repairs as may be required. A copy of the Examiner's report, on R.G.F. Form 132, will be addressed by him to the Officer Commanding the Battery for transmission to the Officer Commanding Royal Artillery in the district; the original report will be sent to the Superintendent Royal Gun Factory, Woolwich, for approval, and his decision will be communicated to the Officer Commanding R.A. in the district. The

Examiner will place these reports in the hands of the officer in immediate charge of the ordnance, who will forward them as soon as possible to their respective destinations. Should there be no ordnance in a district requiring examination or repair, the district will not be visited during that tour.

Western district. In part of the western district comprised in the counties of Somerset, Devon, and Cornwall, the qualified Master Searcher of the Ordnance Store Department will, on requisition addressed to the Senior Ordnance Store Officer of the district, perform the duties which in other districts at home are performed by the examiners and artificers from the Royal Gun Factory.

Master Searcher's reports. The Master Searcher's report of examination will be sent to the Royal Gun Factory for confirmation, and also reports of work done after approval accompanied by gutta-percha impressions where necessary.

Foreign stations. At all foreign stations the examination will be made under the direction of the Officer Commanding Royal Artillery in the district, by an Inspector of Warlike Stores, should there be one at the station, or, if not, by some other competent person. A report of the examination will be made on Army Forms G 869 and G 872 (late W.O. Forms 1475 and 1476), and forwarded through the same channels as laid down for the Annual Return. In such cases the word "Special" will be substituted for "Annual" in the heading of the form. Impressions will not be sent with the report unless there is any doubt as to the serviceability of the ordnance examined; but should any piece appear to be in an unserviceable state, or to require repairs beyond what can be effected on the spot, impressions will be forwarded with the report, for the information of the Director of Artillery and Stores, who will give such directions as he may think desirable.

Ordnance in important positions. If ordnance which are mounted in important positions are found to be unserviceable or to require repair of a nature that cannot be performed on the spot; or if local circumstances render their immediate exchange necessary, they will be at once exchanged if practicable, by requisition on the Senior Ordnance Store Officer, approved by the General Commanding. In such cases, the requisition, after being complied with, will be forwarded by the Ordnance Store Officer to the Director of Artillery and Stores.

Guns on board ships at home. Officers Commanding her Majesty's ships at home will, as the exigencies of the service permit, when a piece requires to be examined, in consequence of its having fired the prescribed number of rounds since previous examination, or for any other cause, forward a return on Army Form G 872 for M.L. or G 925 for B.L. guns to the Senior Ordnance Store Officer at the station or district, with a request to have the piece examined. After examination the sentence will be entered on the above form, which will be delivered to the Officer Commanding the ship,* to be sent through the proper channel to the Secretary of the Admiralty, for transmission to the War Office.

Guns on board ships abroad. Officers Commanding her Majesty's ships abroad will, under similar circumstances, forward a request that the piece may be examined, with a return on Army Form G 872 for M.L. or G 925 for B.L. guns, to the Senior Ordnance Store Officer at one of the stations where there are Inspectors of Warlike Stores, viz.:—

Barbados.	Ceylon.	Hong-Kong.
Bermuda.	Gibraltar.	Malta.
Cape Town.	Halifax.	Mauritius.

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* The Officer Commanding should, before forwarding this return to the Admiralty, extract all the information required by him to complete his next annual return.

CHAP. I.

The Ordnance Store Officer, on receipt of such requisition, will make a demand upon the Officer Commanding Royal Artillery, for the examination to be made by the Inspector of Warlike Stores. On the completion of the examination, the sentence will be entered by the Inspector of Warlike Stores on Army Form G 872 for M.L. or G 925 for B.L. guns, which will be sent to the Ordnance Store Officer for transmission to the Officer Commanding the vessel. This latter officer will take such steps as he will deem necessary under the orders of the Senior Naval Officer.

Reventing stations.

The only foreign stations at which rifled ordnance can be revented are Bermuda, Ceylon, Esquimault, Gibraltar, Halifax, Hong-Kong, Malta, and Simon's Town: but venting tools are now generally supplied to the flag ships in every fleet.

Esquimalt and Simon's Town.

As there is no Ordnance Store Officer at Esquimalt, or Simon's Town, application will be made to the Head of the Naval Establishment for the service of the Naval Engineer Officer stationed at these places.

When an I.W.S. is not available.

Should the services of an Inspector of Warlike Stores not be available, through the ship being at sea or from any other cause, the examination may be carried out by a Naval Officer possessing a certificate of competency to examine naval ordnance, and make the necessary recommendations for minor repairs or provisional condemnation. After provisional condemnation such pieces will not again be used until an examination has been made by a qualified examiner at home, or an Inspector of Warlike Stores abroad, and sentence passed in due course.

Sea-going vessels.

No ordnance on board a sea-going vessel should be sentenced otherwise than *serviceable* or *unserviceable*, except in regard to minor repairs, which can be carried out at once on the spot. In a doubtful case the ordnance should be provisionally condemned.

Royal Marine Artillery, Royal Naval Artillery Volunteers, Royal Marines, &c.

Officers Commanding Royal Marine Artillery, Royal Marines, and Royal Naval Artillery Volunteers, and Her Majesty's Coast Guard and Royal Naval Reserve batteries, on shore, will, when a gun requires to be examined, forward, through the proper channel, for transmission to the War Office, a return on Army Form G 875, together with gutta-percha impressions of vents and important defects observed in the bore and powder chamber.

After examination of these impressions, and also when ordnance are inspected by examiners from the Royal Gun Factory or from Ordnance Store Departments, at Devonport and Portsmouth, the result will be notified to the Officer in charge.

If no person competent to take impressions be available, application should be made to the Senior Ordnance Store Officer of the district to have this service performed.

Impressions of guns revented.

In every case where a gun is revented, impressions of the vent, both before and after rebushing should be forwarded through the proper channel for the information of the Superintendent Royal Gun Factory.

Inquiry into the cause of accidents.

When any accident occurs, either at home or abroad, such as the bursting of a shell in the bore, the splitting of an obturating cup, the failure of a vent-piece, &c., immediate inquiry will be made into the circumstances, and the ordnance examined. If the Commanding Officer considers the damage to be of importance he will send without delay a report of the circumstances through the same channel as his Annual Return, forwarding, if necessary, for illustration of his report, gutta-percha impressions of the damage done.

Memorandum of Examination, p. 371.

Every rifled gun issued from the Royal Gun Factory is accompanied by a "Memorandum of Examination," which contains a record of the material of the bore, and of the number of rounds fired, as well as the particulars of any slight defects which may exist in the piece at the

date of issue; for the new B.L. guns separate columns are also provided for the breech fittings. This Memorandum will remain in charge of the officer who has possession of the ordnance, and a certificate to the effect that it is in possession, and complete up to date, will be included in the Annual Return of Rifled Ordnance, Army Form G 872 or G 925 as the case may be. At the conclusion of each day's practice with any piece, an entry will be made in the Memorandum by the officer in charge, giving a detail of the rounds fired (including blank charges), so that an accurate record of the firing may always be kept up. The results of examination after approval by proper authority will be added to the Memorandum by the officer in whose charge the piece may be at the time when the examination is carried out; and when the gun is returned into store, the Memorandum will accompany the transfer vouchers. If at any time the Memorandum be lost or damaged, a duplicate can be obtained through the Admiralty or War Office from the Superintendent Royal Gun Factory. Inside sheets, for continuation of the record of the number of rounds fired, can be obtained on demand from the Ordnance Store Department.

Periodical examination. In a periodical examination it will generally be sufficient to take impressions only of the more important parts of a gun. These are—

(*a*) For S.B. ordnance: the vent and a small portion of the bore immediately around it.

(*b*) For R.M.L. converted guns, and all others which have iron barrels: the whole of the powder chamber, and the end of the bore showing the joint where the cup is screwed into the barrel; also the upper part of the bore for 2 feet from the chamber, when there is any scoring in the gun.

(*c*) For R.M.L wrought-iron ordnance, having steel barrels: the upper part of the powder chamber showing the bottom of the the vent, and the upper part of the bore for 3 feet from the commencement of the rifling, showing the contraction of the bore when the powder chamber has greater diameter than the calibre of the piece.

(*d*) For R.B.L. guns: impressions need only be taken where flaws can be seen.

(*e*) For B.L. guns: a complete set of the chamber, showing the obturating ring, front slope, and commencement of the rifling; also of scoring and flaws if seen in the bore.

Examination of Vent.

Examination of vent. There are two points to look to in the examination of a vent, viz.: the size of the channel, and erosion of metal round the bush in the bore.

Through gauge. The size of the fire channel is ascertained by passing down gauges of increasing diameter, a set of which will be found with the examining tools. The channel should be first thoroughly cleared, for in a copper bush it is not uncommon to find a "choke" where the metal has been set up at the bottom of the vent; this should be removed by a vent-rimer before the through gauge is recorded.

Limit of through gauge. As a rule the following diameters may be taken as the limit of size for the vent in different natures of ordnance:—

(1) S.B. and converted R.M.L. guns.—When the 0·3-inch gauge will pass down.

(2) All other rifled ordnance.—When the through gauge is 0·275-inch.

Erosion in the bore. With regard to erosion in the bore, this generally takes the form of a ring (or part of a ring) round the end of the bush. Fissuring also will

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be frequently found round the bush and in front of the vent. In some instances the channel may be distorted in an extraordinary way, and the whole end of the bush may occasionally be set up or appear to have been fused away. If the gun has been bushed at some foreign station or on board ship, it will often be found that the powder has got into the cone, and sometimes into the threads of the screw, owing to bad workmanship in the operation of venting. This kind of injury will be of a serious character, and the Inspector of Warlike Stores must exercise his judgment in giving a sentence on the gun; a few rules may be offered for general guidance.

G.P. impression of vent.

First a clean and sharp gutta-percha impression must be taken to show clearly the extent of damage in the bore. This can only be done with the instrument which is supplied for examining guns (a plate being always selected to fit the form of the chamber), or with a similar kind of machine which is provided among the tools for reventing.

Use of the instrument supplied with reventing tools.

In using the latter instrument a small piece of prepared gutta-percha must be placed on the pan, which should have previously been fitted with a pad of the same material to get the curve of the bore; this is screwed up against the bottom of the vent. In ten minutes it will probably be cold enough for withdrawal if the bore has been greased; care should also be taken to soap the pad to prevent the gutta-percha from adhering to it. Too much pressure must not be applied or the impression will turn out very thin, and if the injury is deep it will then be difficult to extract the gutta-percha; while any portion left in the defect must prevent the possibility afterwards of taking a reliable impression at all.

Unbushed cast-iron guns.

In unbushed cast-iron guns the erosion will take the form of an irregular cavity, fissuring out perhaps in several directions. Cracks and hair-lines may also appear. The extent of the cavity must be measured from the centre of the vent channel as nearly as that point can be judged; if the longest fissure does not exceed 0·35 of an inch, the gun can be cone-bushed; if it extends further but not more than 0·5 of an inch, a through bush should be put in. If a through bush will not remove all the defect the gun must be provisionally condemned. A little roughness of surface beyond half-an-inch may often be removed with a file before the bush is screwed in.

Copper-bushed guns.

In guns that have been copper-bushed, whether the material of the bore be of iron or steel, the cavity will generally present the appearance of a hollow ring. As long as this wear of the metal is uniform, and the edges are not rough and jagged, it is of little importance; but to maintain the guns in perfect order for service, rebushing may be carried out more often than is absolutely necessary.

Fissures and hair-lines.

Fissures radiating from the edge of the bush will be very commonly found, especially in front; and hair-lines or cracks may possibly be discovered starring out in any direction. These should always be removed with a file if possible at the time of reventing; the extent to which filing may be carried must be left to the judgment of the examiner or artificer performing the work.

When the ring is worn away, as shown in the accompanying figures, to the depth of 0·1 of an inch, or to a width of 0·075, in R.M.L. ordnance or 0·1 in S.B. pieces, or when (as stated before) it is jagged and irregular, and likely to retain a piece of unconsumed cartridge, the gun will be condemned for rebushing, and, if possible, with a cone bush. Much wear of the lower portion of the fire-channel also will necessitate the reventing of the gun. The amount and nature of wear must be left to the judgment of the examiner. Generally speaking, if any sign of fissure of the copper is apparant, or if the thickness of the wall is much reduced in any part, the bush must be

FIG. I.

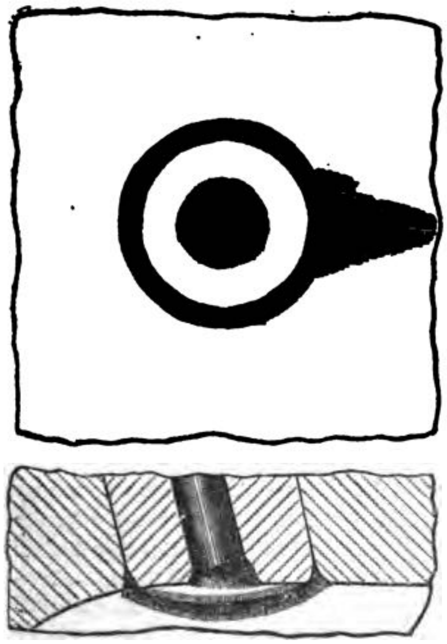
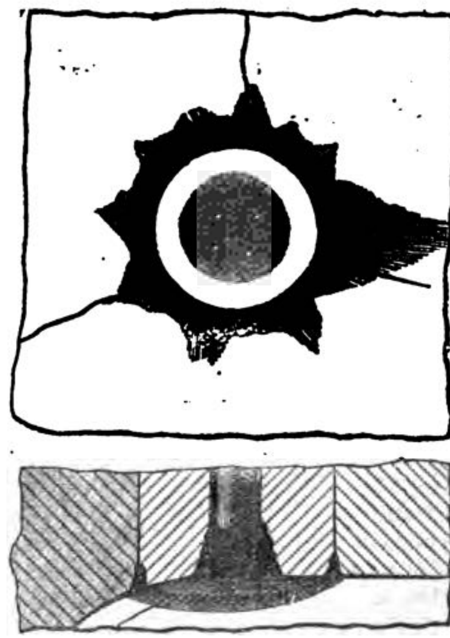


FIG. II.



condemned. In case of hair-lines radiating to the right or left from the edge of the bush in steel-lined pieces, the gun must be provisionally condemned should they be 1 inch in length; but when directly to the front or rear, half-an-inch may be taken as the limit for condemnation, for that position is the worst for the development of a crack.

Fissuring in front of the vent.

In heavy ordnance fissuring in front of the vent (caused apparently by the rush of gas through the vent channel) will often be rapidly developed. This fissuring partakes at first of the nature of scoring; if not attended to it may increase in depth to a crack. Such roughness should therefore be filed out, and an examiner must use his discretion as to when this operation is necessary, but in no case should it be allowed to attain a depth of 0·075 inch.

Discretion as to sentence.

Although a properly instructed examiner will generally be able, with the aid of these rules, to sentence a vent either as serviceable, or for rebushing, yet cases will arise (except in sea-going ships) in which it will be advisible for the vent to be sentenced as fit for some reduced number of rounds, and then to be further examined. Such cases must be left to the discretion of those whose duty it is to give sentence on the gutta-percha impressions taken.

Removable bushes.

When guns are provided with removable bushes, these should, after gauging, be taken out and inspected for cracks, and for the condition of the screw-threads on the exterior. The amount of scoring also at the mouth should be reported upon, the bush not being condemned until such enlargement approaches the outer edge of the metal. Axial bushes adapted for vent-sealing tubes should be gauged in the cone; when these also form the spindle for an obturating cup or pad, additional care must be displayed, both within and without. Radial bushes are liable to more rapid scoring than axial bushes for vent-sealing tubes, but they are short and can be easily examined by holding them up to the light; when much corroded they should be exchanged.

To examine the axial vents of 12·5-inch (Mark II.), 16-inch, and 17·72 inch R.M.L. guns, the gun-metal cover or socket must be taken

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off and the vent-nut removed with a wrench supplied for the purpose; the double key can then be taken out, and the bush pushed forward on to the cradle, by which it is withdrawn. Before reventing, the shank of the acorn guide should be inserted in the vent, and it can then be replaced and secured.

In B.L. guns which are fitted with removable vents in a radial position, the bush is removed by taking off the nut with a wrench, and pushing the bush into the bore. In replacing it, the vent is turned round till the slot in the bush is opposite the feather in the gun; it is then pushed up to position and secured as before.

Care should be taken with all removable bushes that they are kept screwed up tight by the nut, as there is always a tendency for the copper washer to be compressed by firing, and an escape of gas may then take place, injuring the gun.

What prop. Q.

Examination of the Bore.

Preparing ordnance for examination.

Prior to examination of the bore it is necessary that the gun should be thoroughly cleaned; it is not possible to detect small defects, which may sometimes be of importance, if the bore be in a rusty or very greasy condition. If care had been previously taken in keeping a gun tolerably clean, it will probably be sufficiently prepared for examination by washing, brushing, and drying with tow on a clean sponge-head. If, however, there be hard rust which will not yield, or a thick coating of lacquer or grease, the bore may be cleaned either by firing one or two scaling charges, *i.e.*, about one-third the full service charge (without projectile), which will usually loosen the scale, or by the use of hot water and potash, in the following manner:—

Method of cleaning with potash water.

About a gallon of boiling water is poured on one pound of black American potash, and an old sponge covered with a canvas cap, or some substitute to make it tight to the bore, is dipped into the solution. The bore is rubbed till the dirt is loose, when the hard brush will remove it; the bore is then wiped dry with tow, &c., and slightly oiled. The potash water must be used very hot, and the sponge must be very tight, or the process is ineffectual. If the dirt be very thick in the small grooves of the R.B.L. guns, a common pricker with blunted point may be useful. No sharp-edged or pointed scrapers should be employed for cleaning the bores of rifled ordnance: they are unnecessary, and liable to injure the rifling.

Lamp and searcher.

The bore when cleaned should be examined first by the aid of a lamp; if the surface is slightly wet the detection of any defect is greatly facilitated. A pointed searcher may be used to ascertain the position and extent of a flaw; and a spring searcher also may prove to be useful in R.B.L. guns if applied in such a manner that each groove shall be traversed in succession by one of the points.

G.P. impressions.

If a permanent impression is wanted, it must be taken with gutta-percha, and instruments are supplied which will generally meet the requirements, but extemporary arrangements have sometimes to be resorted to by the examiners.

Instruments.

The instruments for taking gutta-percha impressions of the bore are all of the same character, but differ in size. No. 1 instrument with spare plates is adapted for the 40-pr. guns (M.L. or R.B.L.) and 6-inch B.L. and all larger calibres up to 12·5-inch inclusive. No. 2 instrument with suitable plates is used for all smaller natures. Special instruments are supplied for the 16-inch and 17·72-inch R.M.L. guns, and also for the chambers of 12·5-inch Mark II. and all B.L. guns of new type.

Wood blocks.

When a proper instrument is not available, wood blocks may be used such as those hereafter described for taking a whole length impression

of the bore. These can be made by any carpenter, and are therefore not issued with examining tools. It requires much practice, however, to obtain thoroughly good impressions with them, so it is advisable to take the powder chamber, the region of the vent, or any special defect in the gun with the instrument whenever it is possible.

Gutta-percha. The best gutta-percha is usually supplied for this service, but a common kind used by shoemakers, or packing of hydraulic valves, will equally answer the purpose. It can be used over and over again, and need never be thrown away if a little new material is added from time to time, to prevent it from becoming too brittle. Care should be taken to keep the gutta-percha quite free from dirt; and it should be placed in water until required for use.

Preparation. The method of preparing the gutta-percha is as follows:—A sufficient quantity is thrown into boiling water and left until soft; a steam tank is suitable for this, because the water must not be kept on the boil, otherwise the gutta-percha would soon become spoilt. It must then be kneaded on a smooth board to expel all air and water, in order to obtain a smooth surface.

Partial impression of the bore. For an impression of a portion of the bore the gutta-percha must be drawn out on the plate of the instrument, taking care that it is not too thick or too broad, and that the surface is quite free from bubbles, creases, and specks. When the instrument is inserted in the gun (and this must generally be done with great care) it is screwed up, and allowed to remain there for 10 to 20 minutes (according to the temperature of the air) until the gutta-percha is sufficiently firm.

A little soft soap, oil, grease, or common soap and water, will prevent the impression from sticking to the pad; the bore also should be slightly oiled. Too much pressure must not be applied when screwing up, or the impression will be thin, and when the defect is very deep it will be difficult to withdraw the gutta-percha. Some practice is required to get good impressions, and several may have to be taken before cracks and hair-lines can be distinguished.

Whole-length impressions. When whole-length impressions are required, blocks and wedges must be prepared according to the drawing on the next page. The blocks marked A (which for B.L. guns should taper from the centre to each end, and for M.L. guns from the breech end to the muzzle) must be shaped to suit the diameter of bore, leaving nearly quarter of an inch for the thickness of gutta-percha. When in constant use they might be bound on either side with hoop iron. The upper surface must correspond to a quarter of the bore. The wedge or wedges should be of a size to permit of their being driven home; they may require to be bound with iron at the end, and a hole is usually put through the projecting part of the wedge which will be found very useful at the time of extraction.

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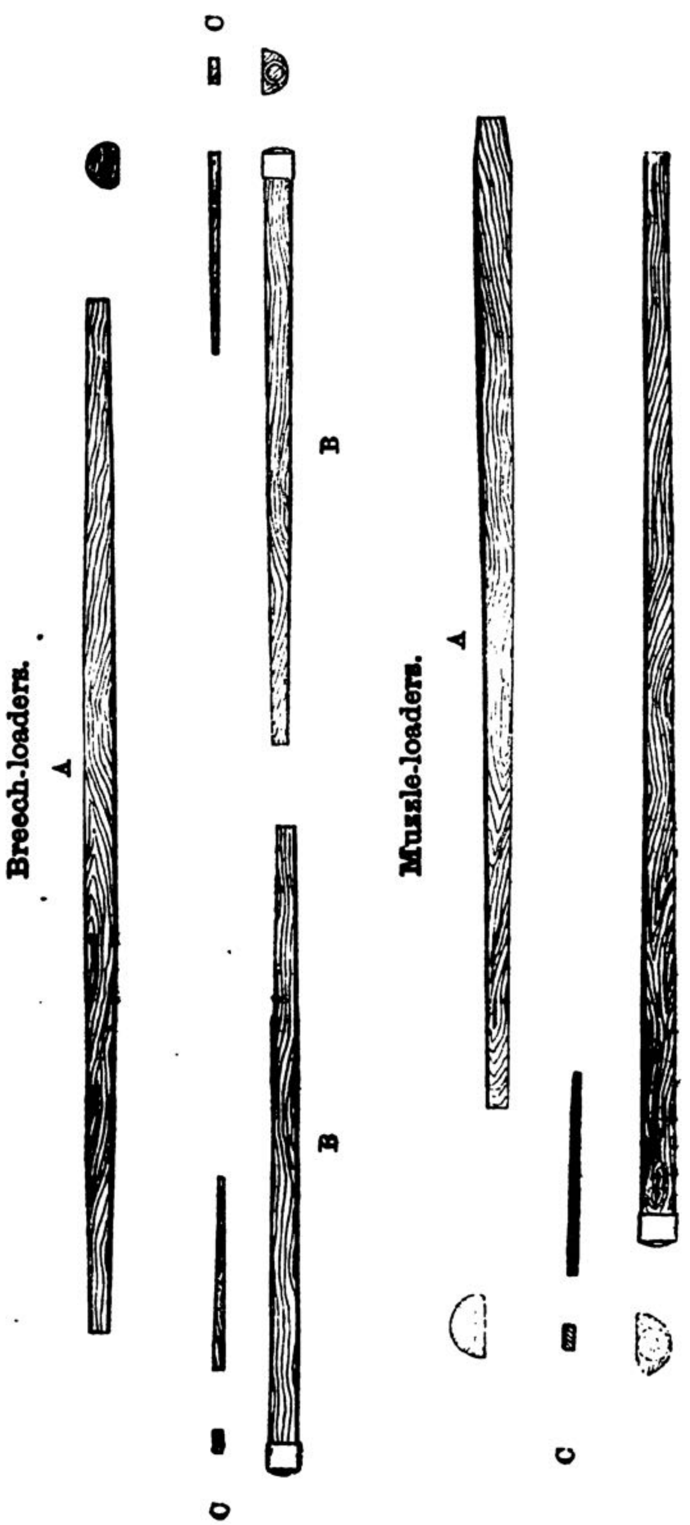
WOOD BLOCKS FOR TAKING IMPRESSIONS OF THE BORES OF GUNS.



The mode of use is shown in the figure below; the gun must be placed so that the impression can be taken against the upper part of the bore, the block A with gutta-percha carefully spread is then inserted in the gun and held up in contact with the bore. The wedge B (or two

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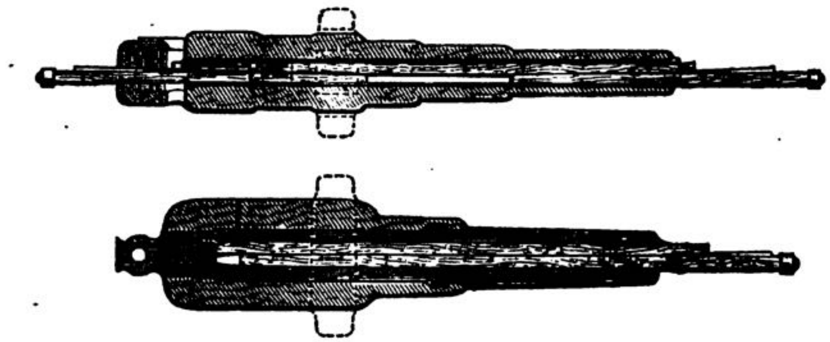
METHOD OF USING THE WOOD BLOCKS FOR TAKING GUTTA-PERCHA IMPRESSIONS OF THE BORE.



wedges in breech-loading guns) is then driven well home with mauls. When working at both ends the blows should be given simultaneously, to prevent the gutta-percha being torn in the bore; and a small piece of wood is generally forced between the block and the wedge, which is particularly necessary in case of an enlarged powder chamber.

Position of defects.

In order to note in returns the position of any flaw or defect, the bore is divided into four parts, *Up*, *Right*, *Down*, and *Left*; the spot may also be more particularly indicated as lying *Right or Left of Up*, *Right or*

Left of Down. The distance down the bore is always measured from the muzzle both in M.L. and B.L. ordnance, except in the chamber of *R.B.L.* guns, when the measurement is taken from the breech; the quartering of the chamber in this case is similar, but right and left always refer to the position of the examiner at the gun.

Circumferential defects are noted round the bore in the direction of the movement of the hands of a clock; *e.g.*, a defective weld might be described as extending from Up to Right of Down at 32 inches, or a coil-mark from 27 inches Right of Up to 29½ Left of Down.

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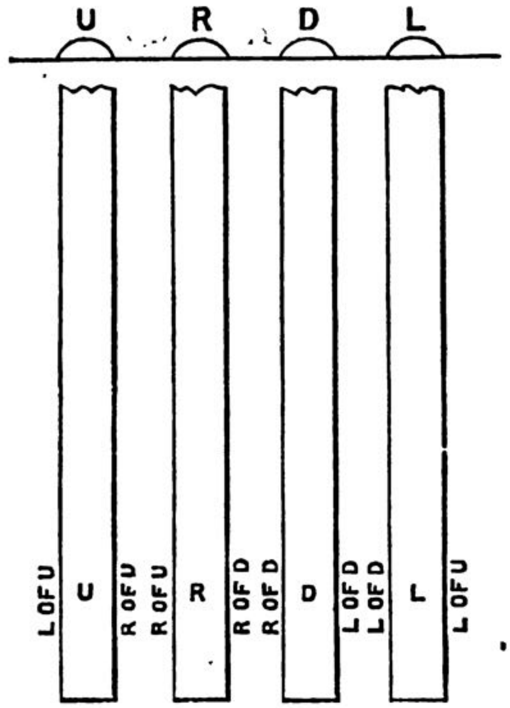
IMPRESSIONS ARRANGED FOR RECORDING DEFECTS.



MUZZLE ENDS.

Labels. When an impression is forwarded with a return, a lable must be gummed to the back, showing the name of the ship, corps, battery, or station, the date of taking the impression, the direction of the muzzle, the nature and number of the gun, and the position of the fissure or defect (if it be in any part other than round the vent bush) defined according to rule just explained.

The impressions should be reduced to the smallest dimensions compatible with showing the whole of the defect.

Examination by means of electric light. The bores of all guns can now be examined, at all stations where there are dynamo machines, by means of the electric light. A full description of the instrument supplied for this purpose will be found at p. 330, and with it any flaws or defects in the bore can be at once detected, photographs taken of them, and forwarded, accompanied, if necessary, by impressions of the defects.

Defects in the Bore.

Cast-iron S.B. guns. In cast-iron guns the bore is liable to be corroded if exposed to the weather, and snow, or to the action of salt water and spray near the sea; occasionally also a flaw in the metal may occur. Generally speaking, however, the defects which condemn such pieces will be found in the vicinity of the vent.

It is not easy to lay down any rules to guide an examiner in provisionally condemning a piece: a great deal must be left to his experience and judgment: but for cast-iron ordnance it may generally be stated that cavities less than ·1 of an inch deep in rear of the trunnions, and less than ·2 of an inch in the muzzle end of the bore, need not cause suspension of firing, unless the edges are jagged and liable to retain pieces of cartridge.

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Rifled guns. With rifled guns the defects which are likely to be found may be classed under three distinct headings, viz.: (1) Original, (2) Fair wear, and (3) Accidental.

Tool marks. (1) *Original flaws.*—These are generally "tool-marks" or slight irregularities and scratches caused in manufacture during the boring and rifling. A chip of steel or grain of sand getting between the machine and the surface of the bore will cause marks of this kind, while the emery powder may leave very fine marks, and the process of lapping often develops a coil-mark or scratch into a flaw of considerable magnitude.

With steel tubes, on account of the hard surface of the metal, fine lines become very apparent, and they have at times been mistaken for cracks when running lengthways in the bore. To an experienced person, however, the difference is easily recognised.

Fair wear. (2) *Fair wear.*—There is a great variety of defects which may be included under this head. In many cases they depend upon the material of the A-tube.*

Scoring. "Scoring" is caused by the rush of gas out of the chamber and over the top of the projectile in R.M.L. guns where there is considerable windage. It takes the form of longitudinal furrows, some of which will generally increase more rapidly than others and become deep irregular channels. All guns are liable to this kind of wear; in small pieces of ordnance it may be slight, but when heavy charges are used the surface of the metal is soon eaten away to a serious extent. In B.L. guns and M.L. ordnance which have enlarged chambers, the chief scoring will be found on the front slope of the chamber and thence for 2 or 3 feet down the bore. In unchambered guns the deepest part will be over the seat of the projectile, and along the loading side of the grooves.

Limit of scoring for gas-checks. It is worthy of notice, that scoring has never caused the destruction of a piece on service, though it must tend towards failure of the tube eventually. Guns have formerly exhibited an enormous amount of erosion, but since the introduction of gas-checks the furrows have not attained any very great size; the erosion continues, however, and it is necessary to place a limit on the depth when gas-checks ought not to be used on account of the risk of their being torn off in the bore. Gas-checks should not be used when the erosion exceeds 0·125 inch in depth at any part. It will be necessary always to state in the column for remarks on the Memo. of Examination, as well as on Army Form G 875, whether the bore is in a sufficiently good condition for firing with gas-checks.

Scoring in B.L. guns. Should the scoring on the front incline of the powder chamber in B.L. guns become 0·05 of an inch in depth, especially if it appears in longitudinal streaks of 1 inch or more in length, impressions should be taken and forwarded, through the usual channel, to the Superintendent R.G.F. Impressions of the powder chamber should extend from the termination of the thread in the breech of the gun and include a few inches of the rifling.

The depth of erosion can be measured with sufficient accuracy from the gutta percha impression by laying a straight-edge (held parallel to the bore) on the top of the raised part of the impression, and then measuring with a compass the height of the straight-edge above the proper surface of the bore or groove.

Wearing of grooves. "Wearing of the grooves" may take place in all rifled guns, but

* The material of which the barrels are made has for some years past been stamped on the face of the muzzle, and it is also entered in the "Memorandum of Examination."

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more especially in R.M.L. ordnance, with which studded projectiles are used; it will generally be noticed in guns which have iron barrels, and in those with steel tubes, which have a uniform twist in the rifling. Scoring will tend to obliterate very shallow grooves, but the result is rough and irregular. The wear from friction will present a different appearance, and it is of greater importance because the studs might at last "override," or get shorn off in the bore.

Coil-marks and defective welds.

"Coil-marks" and "defective welds" can only appear in guns which have a tube of coiled iron. The term coil-mark is applied to the lines which may be found running spirally round the surface of the bore, due to the manufacture of the A-tube by coiling, where the weld has not been quite perfect. They are generally not very deep, and consequently are of little importance. When, however, they happen to be large or serious in character they are called "defective welds." This term is also applied to a defect at the junction of different lengths, from imperfect work in the process of uniting together: in this case the flaw would run circumferentially. Unless there is reason to believe that a defective weld is rapidly increasing, or some material change is observed from its state at a former inspection, the gun need not on this account be condemned. Speaking generally, the *depth* of a defect is of more importance than its extent, but should a defective weld run right round the bore, or even two-thirds of the way, the piece would be liable to break in two at this part, and it should then be recommended for exchange.

Specks, spots, and flaws.

"Specks," "spots," and "pin-holes" are terms applied to small cavities in iron barrels, which are generally produced by cinder or dirt in the iron, or by blisters, &c. They sometimes occur in clusters, and are usually disclosed to view after the surface has been removed by erosion and firing. Large defects of this nature are generally called "flaws" for distinction.

Position as a point of importance.

Experience has proved that flaws, and defective welds are of little importance in guns not exceeding the size of the 7-inch B.L. screw gun. The importance depends in a great measure on the position of the defect, one in rear of the trunnions, and especially in the powder chamber, being more dangerous than one of the same nature and extent in the forward part of the bore, because the powder gas will act much more rapidly upon it, and if ragged it might hold a piece of ignited cartridge. Very few instances have occurred in which coil-marks have been the cause of an accident, or in which the defects have increased to any material extent after issue, unless such defects have been situated in the powder chamber, and for this reason no guns have been issued for many years past with any but very trifling flaws in that part of the bore.

Longitudinal fissures.

"Longitudinal fissures" are peculiar to iron barrels, but only to those which have been made out of solid forged iron. They are caused by the erosion of gas along the lines of the forging, and may be due to defective welding sometimes. When these fissures are fairly developed they weaken the barrel (already too weak in a circumferential direction), and therefore they should always be regarded with suspicion.

Cracks.

"Cracks" may occur in iron or steel, but it may be said that they are almost restricted to barrels of steel. Steel is free from most of the defects inherent to iron, and generally shows a perfectly clear surface at first, excepting tool marks. Cracks caused by fair wear usually take a longitudinal direction, and then they naturally follow (if they do not originate in) the driving edge of a groove. It is necessary to distinguish between fissures and cracks, for a crack is at all times sufficient to condemn any piece, although many rounds may sometimes be fired from it with safety after failure of the barrel. This has been proved

by firing under precaution one or two guns in which the barrel was split, but on service the gun should always be immediately exchanged.

Accidents. (3) *Accidental.*—In this class we must place all cracks, dents, and abrasions caused by the premature explosion of a shell in the bore, as well as all injury from shot, splinters, &c., and failure of the piece by explosion.

Dents and abrasions. Dents and abrasions are of little importance, for generally any roughness can be remedied by filing. Cracks are serious; when these are due to the explosion of a shell they will be found near the muzzle, and they will run irregularly through the metal, sometimes dividing off in several directions. In one or two instances the muzzle has been blown away altogether. A short crack may be stopped by a clever artificer by boring a circular hole at the extremity of the crack; this must be carefully plugged flush with the bore, but the remedy would only be resorted to on active service, or until the gun could be exchanged for another.

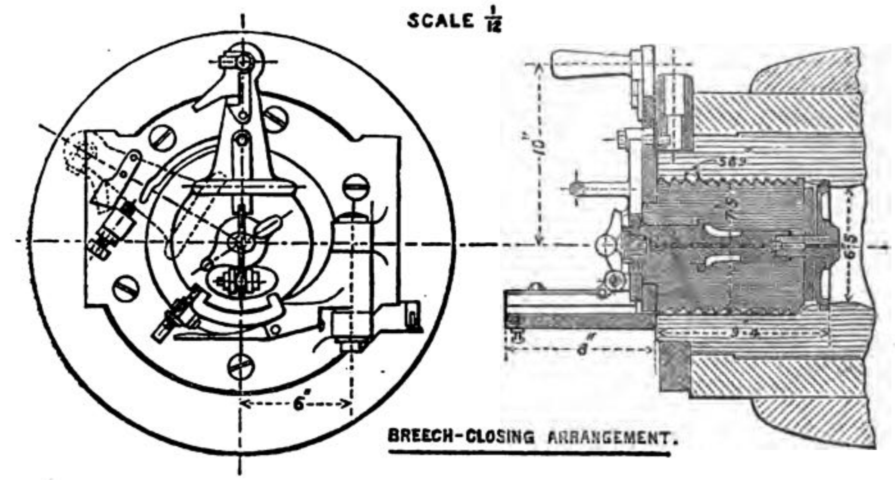
Further firing in case of doubt. When the examiner is in doubt as to the nature or importance of any defect, and when circumstances also permit, it is well to fire a few rounds and then take another impression; if on comparing this with the first, the defect does not appear to have increased, the gun may be considered serviceable for another series of rounds.

Examination of B.L. Fittings.

The following instructions have been prepared for examining the fittings on different natures of breech-loading guns :—

6-INCH (80-PR.) GUNS.

SCALE $\frac{1}{12}$



BREECH-CLOSING ARRANGEMENT.

Bolt, vent. Examine thread of vent-bolt, ascertain if the nut works correctly and the spring be sound.

Bracket. The bracket should be free from burrs, and allow of the ready entrance of the lever-catch of the carrier.

Carrier. Carrier complete, with hinge-pin, washer, and keep-pin. Especial attention should be paid to the lever-catches of the carrier, and to the soundness and good working of their springs.

Cups, obturating. The obturating cups should be turned round when on the breech-screw, and their outer edge carefully inspected for marks and lines indicative of gas in motion. Any such defect on the exterior of the lip

would condemn the cup; cracks in the steel should also be looked for. The back should be tested with a straight-edge.

Burrs on cups.

Care should be taken that the edge of the cup is kept uninjured and free from burrs. Should any burrs or notches be observed, the cup should be removed and replaced by another.

Abrasions on cup.

Abrasions on the edge of the cup can generally be removed with a dead smooth file. The proper action of the cup depends upon the slightly convex form of the base upon which it rests. Each time the gun is fired the flat underside of the cup is forced by the pressure of the gas to take the form of the base, and the circumference is thereby expanded so as to tighten against the ring of copper which surrounds it. If the underside of the cup should by continued firing partially lose its flatness, and take a permanent hollow form, it may be packed up by inserting beneath it one of the thin brass discs provided for the purpose. These discs are of two thicknesses to meet different degrees of hollowness. The hollowing of the underside of the cup will always manifest itself by a diminution of resistance to the tightening of the lever against the stop.

Brass discs.

Cup to be removed.

When the gun is not likely to be required for immediate use the steel cup should be removed from the breech-screw, and kept in a dry place, oiled and free from rust.

Removing a cup.

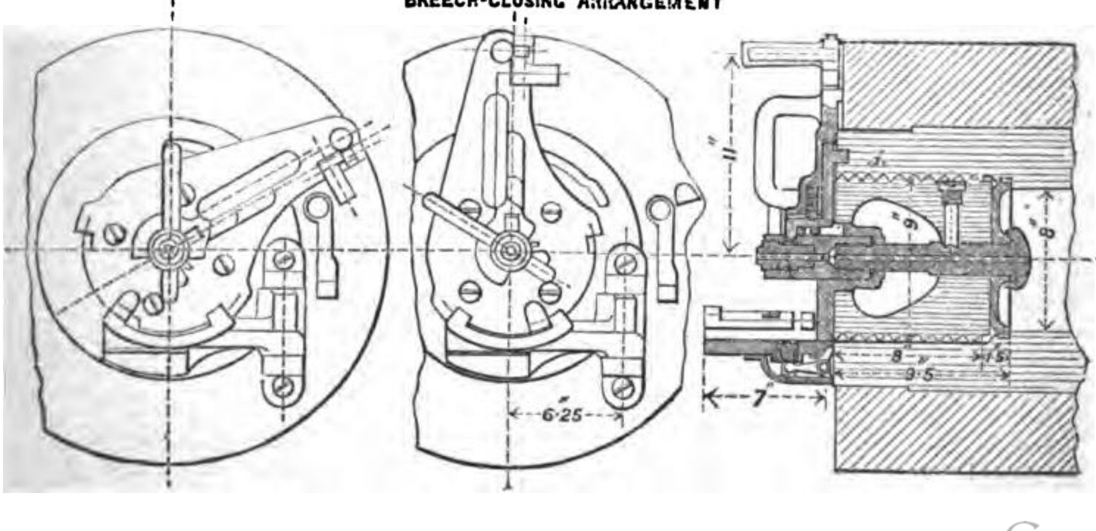
To remove a cup hold the key provided for this purpose on the flat sides of the head of vent-bolt to prevent turning of the cup, and use another key (forked) to unscrew the nut of vent-bolt. This will free the cup, which can be withdrawn to the front. The vent-bolt should be then unscrewed from the cup and the washer and nut taken out to the rear.

Replacing a cup.

To replace a cup screw the vent-bolt, with three brass discs beneath it, on to the cup, put the cup into position, and then from the rear arrange the washer, so that the key guide on it fits into the slot in the vent-bolt; now put on the nut, screwing it up with the forked key, and holding the vent-bolt head with the hand. When the nut is nearly home force the breech screw into position in the gun, so as to centre the cup, then withdraw the screw, and holding the vent-bolt head with one key, screw up with the other.

6-INCH GUN, MARK II.

SCALE $\frac{1}{12}$.
BREECH-CLOSING ARRANGEMENT



Both electrical and mechanical holders should be sound, the mouth uneaten by gas; the needle should be taken out of the latter, and that and the small spring inspected for soundness.

Lever. The lever with its handle should be sound; the firing hammer inspected as to the nose, and that no crack exists at the junction of the weighted head.

Removing cup and vent-bolt. To remove the cup and vent-bolt, unscrew the set screw in the upper relieved portion of the breech-screw, which enables the cup and vent to be withdrawn to the front. Reverse the operation in replacing the cup. In all reports the number of the cup is to be shown.

No. of cup to be quoted.

B.L. Guns having "Cup" Obturation.

Breech-screw. *Breech-screw.*—A gauge is issued for inspection of this fitting. The inner edge of it is laid on the smooth portion of the screw and over the curved front; thus any bulge or setting up of the screw would be apparent. The threads of the screw are gauged by the upper edge. Should the screw-threads be found set up, the breech-screw would not be condemned, unless it was found not to work readily in the gun. On the other hand, if a breech-screw were found to jamb in working, this gauge would enable the examiner to detect the defect, which might often be remedied by filing. On no account should any portion of the thread be cut away to remove a crack, &c.

Clip-retaining lever. The retaining clip is fixed to the lever handle by a screw. If the spring be weak the clip may be taken off and a new spring inserted.

Rings, copper obturating. To examine the copper obturating ring, place a light in rear end of chamber, and pass round the top of the finger over its surface for gas marks. The marks will show also on the gutta-percha impressions which should also be taken.

The regulations for the inspection of the cups, rings copper obturating, and breech-screw, are the same for all the above natures.

Carrier. If the carrier be found not to work correctly it should be removed from the gun, and the under plate unscrewed, revealing the mechanism. Two small bell crank levers will be found within, stamped Lever A and Lever B. Their spindles may be unscrewed, the flat spring below lever A or the spiral spring round stop of lever B replaced, or such other parts as may be found damaged.

Catch, clip-retaining, for carrier. The catch and clip-retaining for carrier, and catch clip-retaining and hinge plate, all of which are fixtures on breech, should be inspected for soundness and for proper working when the carrier is attached.

4-inch 13 cwt. and 22 cwt. Mark I.

To remove cups. Wrenches, A and B, are supplied for each of these guns to remove the nuts of the spindle. Take off the nuts of the spindle, the spindle and cup can then be taken out.

B.L. Guns with the De Bange Obturation.

Breech fittings. All the fittings should be examined for cracks and other defects, also for their proper adjustment and efficient working; burrs should be removed by filing, which should be done carefully, so as not to permanently damage the fitting.

Obturator. The obturator consists of the steel mushroom, the obturating wad, and the compound metal discs.

The outer canvas of the wad should be free from rents; small bruises, likely to be removed by the pressure from firing, are of no importance.

CHAP. I.

The metal discs should have their outer rims free from indentations and cracks.

One or more steel discs may be required in rear of the obturator, when the pad becomes compressed from firing: one will generally be found advantageous, but in all cases the obturator should turn freely in the breech-screw.

The obturator required for use is kept complete in the gun, being taken off about once a month, or after firing, and cleaned and oiled, or greased with Russian tallow mixed with oil, or some other suitable lubricant.

The spare wads and discs are kept in the case provided for the purpose, which protects the discs from indentations and bruises, and admits of the wads being kept pressed to the proper size, there being a tendency of the wad to swell in the direction of its axis, which might cause difficulty in fitting the obturator on the breech-screw.

Breech-screw.

Should the breech-screw not work easily when the obturator has been detached, the defect may often be remedied by filing, but no portion of the thread should be cut away to remove a crack, &c.

Clip-retaining carrier.

If when opening the breech the carrier ring remains fast owing to the "clip-retaining carrier" not working properly, the latter can be pushed back by inserting a pricker in the hole provided for this purpose on the left side of the breech.

Steel lining.

Guns fitted with steel lining should be inspected to see that there is no shifting of the lining at either end, and that the powder gas is not producing any opening of importance at the joints; indications of these will be given by gutta-percha impressions, which should in all cases of doubt be forwarded through the usual channel to the Superintendent Royal Gun Factory.

R.B.L. Guns.

Examination of breech-screw.

The breech-screw will be examined with the straight-edge, in order to ascertain that the face is perfectly flat and true; if it be not, it will be filed; the thread should be examined by tapping with a wood mallet, and should not be broken or burred, but a considerable portion may be removed, if injured, without destroying the efficiency of the screw.

Lever, tappet, and keep-pins.

The lever and tappet should be sound. The lever handles of naval guns are sometimes broken off, but the lever can still be used in this state, though not so conveniently. The keep-pins must be sound.

Vent-piece.

The vent-piece is the most important fitting, and should be perfectly sound, neither cracked nor bulged. The back and sides, when tested by the straight-edge, should be quite flat and true. The fracture of vent-pieces is frequently owing to the back not being true to the face of the screw. The copper ring on the vent-piece, as well as the breech-bush at the end of the barrel, must be sufficiently high to prevent the action of the gas on any part of the iron. The angle face of the 7-inch vent-piece should be smooth and should work truly against the angle face of the bush; the foot should fit closely, but not too tightly, into its place. The copper bushes in the neck of the vent-piece should be in good order. If they are so much worn that a ·276-inch gauge can pass through, the friction tube is liable to be pulled out without being fired; the bushes will then be renewed from the spare sets issued for that purpose. A cavity frequently forms at an angle of the vent channel, but this (which should be examined with a probe) does not entail the immediate condemnation of the vent-piece, unless the examiner considers it dangerously large.

The cross-head should not be loose, as instances have occurred of its being broken off whilst firing. In all cases before taking a vent-piece into use, it will be advisable to test the soundness of the cross-head as well as the neck, by tapping with a hammer.

Cross-head.

The breech-bush will be sentenced to be renewed if found to be so much expanded that the gas could escape between it and the tin cup or vent-piece, and when it is not possible to remedy the same by facing. In order to prevent serious damage to gun and vent-piece, attention should be paid, both before and during practice, to the breech-bush in the gun and the copper ring on the face of the vent-piece. If at all dented they should be carefully faced before use. During practice the officer in charge should take means to ensure these points being looked to constantly, and should stop practice with any gun or vent-piece in which eating away of the copper by the escape of gas begins to show itself.

Breech-bush and copper ring.

When this once commences, a few rounds are often sufficient to cause permanent damage.

Examination of Exterior of Ordnance.

Considerable defects may exist on the exterior of wrought-iron ordnance, without the strength being affected. Occasionally, on firing, one of the outer tubes may develop a flaw running round the gun, due to the coil or tube having been in an undue state of longitudinal tension. Such defects are, as a rule, unimportant, and are easily repaired when the gun passes through the Royal Gun Factory.

Exterior.

Defective welds may possibly be discovered in the exterior parts of coiled iron, but these are generally of little importance, and a gun should not be condemned on such grounds alone, though it should be exchanged when an opportunity offers.

Defective welds.

If it be found that a shell has burst in the bore, the exterior ought to be thoroughly scraped with old swords, and cleaned (with potash water, if necessary), in order to ascertain whether it is perfectly sound.

Shell burst in bore.

It occasionally happens with wrought-iron guns that on firing the outer coils shift; if on examination the shifting is found considerable, the gun will be provisionally condemned, but a slight shift, which is sometimes perceptible when the gun is first used, and which has gone no further afterwards, may be disregarded. Unless there be reason to suspect damage on the exterior, it will not be necessary to scrape the whole of the paint off the exterior whenever a gun is examined. Large defects of any kind on the exterior are noted on the "Memorandum of Examination."

Coils, shifting.

The position of a defect on the exterior of a gun is described in a similar way to that mentioned already for defects in the bore, except that the distance is measured from the breech in all except B.L. guns of new type.

Attention should be given to the soundness of the trunnions, and of all parts of the attachment of the elevating gear.

Trunnions and elevating gear.

Although none but authorised Inspectors are permitted to sentence or carry out repairs on a gun, it is highly desirable that every artilleryman should understand how to examine the weapons placed in his charge; and he ought to be able to form some opinion on the nature of any defects which may be brought to his notice. Examinations of ordnance must be searching and very exact, for a small flaw may endanger the life of a piece, and involve the risk of an accident to men who are employed at the gun. The moral effect of the bursting of a piece is much more damaging to the steadiness of troops than the explosion of any number of the enemy's shells: it is therefore highly important that all officers should be able to guard against such a catastrophe by

CHAP. I. suspending the fire when any serious injury may be discovered. On the other hand, it is equally important that the gun should not be thrown out of action on account of injuries, however conspicuous, when they are not really of a dangerous character. Hence it may often depend on the judgment of officers to say whether the state of a gun is satisfactory or not; and the confidence of the gunners must rest on the ability of their officers to decide. This knowledge is more necessary in the present day than it ever was in the history of artillery, for modern guns must be regarded as highly finished weapons of war, which are capable of exhibiting great power and extraordinary destructive effect; but for this very reason they are all the more liable to injury and wear, and it is essential to keep them under observation. In war no doubt risks would be readily incurred, but in times of peace all reasonable precautions should be taken to avoid an accident, and thus experience may also be gained as to the safety and endurance of guns.

INSTRUMENT FOR EXAMINING THE BORES OF GUNS BY ELECTRIC LIGHT.

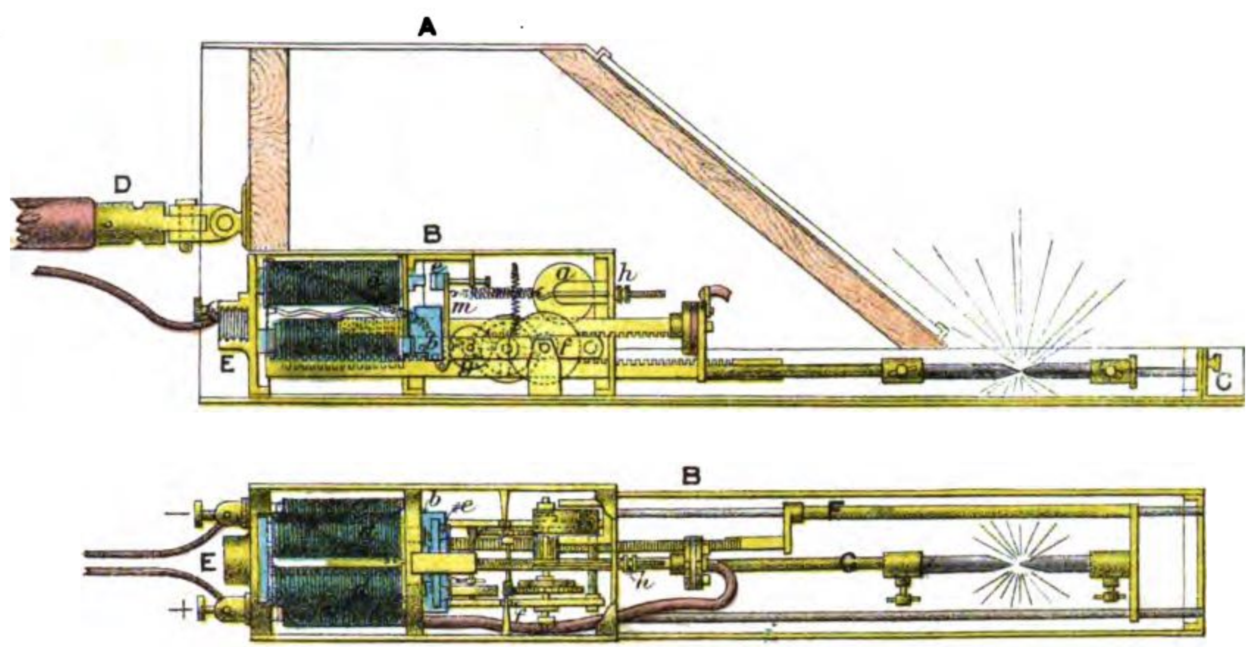
This instrument will be issued at all stations at which a dynamo machine is available for working it, and will not only enable an examiner to get a distinct view of all parts of the bore of a gun, but should any defects show themselves photos of them can be be taken, and forwarded through the usual channel to the Superintendent R.G.F. The instrument can be used for either B.L. or M.L. ordnance.

The instrument (as shown in Plate) consists of a carrier (A), a regulator (B), and a rod (D) for moving the instruments. The carrier (A) is a cylindrical case of sheet brass in which is fitted a mirror at an inclination of 45°, and is so shaped as to allow an image of a portion of the bore of the gun to be cast on the mirror and thence reflected along the axis of the bore: it is fitted with vulcanite rollers which insulate the case from the bore and facilitate movement. The carriers are of different sizes, to suit different natures of guns, and increase in size by intervals of two inches. The regulator (B) is held firmly in the carrier by means of a bracket (C) at the front which carries a set screw, and by the circular aperture at the end of the carrier in the rear. It is an adaptation of the "Brockie" arc lamp, and is contained in a circular brass case of 4 inches in diameter. The rear plate is fitted with a socket for attachment to the rod, when the instrument is used for guns of smaller calibre than 8 inches, and with two terminals for the attachment of the conductors from the dynamo or battery. These are marked "+" and "—."

The carbons are held in two sliding rods marked F and G, which are geared together by a pinion, and so arranged as to keep the arc practically in one position in relation to the mirror; the distance between the two carbons is regulated by means of two electro-magnets. The upper rod which actuates one of the carbons is controlled by a flat coiled spring in the drum (*a*) which is in connection with the rod by means of a flexible cord; a train of wheels carried in a rocking frame. pivoted on the same axis as the pinion, is driven from the pinion spindle and is employed to prevent the too rapid movement of the carbon-holders, the last wheel on the spindle being so constructed as to form a brake. The frame is held up by means of two suspended spiral springs, and is fitted with an armature (*b*) which, when attracted by the lower electro-magnet (*c*), draws the frame down, thus separating the carbons.

To face page 330.

INSTRUMENT FOR EXAMINING BORES OF GUNS WITH THE ELECTRIC LIGHT.



The electro-magnet (*c*) is wound in the main circuit, and when the current passes the armatures they are struck; when the carbons have thus been separated, the further regulation is performed by the upper electro-magnet (*d*), which is wound in a shunt circuit across the arc. The armature (*e*) which is actuated by this magnet forms part of a frame (*m*) pivoted on the rear end of the rocking frame (*f*), and carries a detent which engages a star wheel (*g*) on the brake wheel spindle. When the armature is attracted by the magnet, this detent is moved back, releasing the star wheel and allowing the driving spring to move the carbons, thus shortening the arc a small amount. An adjustable spiral spring is attached to the armature, and by altering the tensions of this spring by means of the nut (*h*) the feed of the carbons can be adjusted. The carbons are supplied the correct length, 13 mm. in diameter for the "+," and 11 mm. for the "—" electrode, to compensate for their different rates of burning.

The rod for moving the instrument is formed in three lengths, coupled up as occasion requires by brass coupling nuts. It is furnished with a socket at the end for attachment to the instrument.

Directions for use.

As the lamp is constructed to be used with an E.M.F. of 45 volts and current not to exceed 12 ampères, it will be necessary to drive the dynamo so as to give these conditions. In order to prevent injury from accidental increase a short piece of the fusible wire supplied should be inserted in the circuit near the dynamo.

The conductors must be attached to the lamp at their correct terminals so that the carbon furthest from the lamp is the "+" electrode; they should be lashed at intervals of about 6 inches to the rod, one of them is then connected to the key box and one to the dynamo. The key must on no account be put in the "key box" until everything is in readiness.

The regulator should be tested before inserting it in the carrier, to see that the lamp regulates satisfactorily. The small nut (*h*) is for this adjustment, and this cannot conveniently be done when the regulator is in the carrier. It is most important that the regulator, when not in use, should be kept perfectly clean in the case provided for the purpose, and on no account should it be tampered with.

In using the instrument avoid all sudden movements, or jerks, which would be apt to throw it out of adjustment.

Carriers of five different sizes are issued suitable for use with guns of the following calibres, viz:—

No. 1	for 6 inches	to	8 inches.	
„ 2	„ 8	„	to 10	„
„ 3	„ 10	„	to 12	„
„ 4	„ 12	„	to 16	„
„ 5	„ 16	„	and upwards.	

For guns of less than 6 inches in diameter, a small mirror is fitted on the regulator, and held in position by means of clamps.

CHAP. I.

TABLE XXXVI.—TOOLS, CLEANING AND EXAMINING S.B. ORDNANCE.

	8-inch and 68-pr.	42-pr.	32-pr.	24-pr.	18-pr.	12-pr.	9-pr.	6-pr.	3-pr.	13″ and 10″ Mortars.	8″ Mortars.	Remarks.
Bits, vent, 17-inch	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Blocks, adjusting, for No. 1 instrument taking impressions of vent	1	—	1	1	1	—	—	—	—	1	1	
Braces, smiths'	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Brushes { gun, with stave, hard round	1	1	1	1	1	1	1	1	(*c*)	—	—	
Brushes { soft or Turk's head { large	*a*	—	—	—	—	—	—	—	—	*a*	*a*	
Brushes { soft or Turk's head { small	—	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	—	—	
Drills, vent, 15-inch	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Gauges, vent (set of 4), 15-inch ...	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Holders for scraper	1	1	1	1	1	1	1	1	—	1	1	
Instrument, taking impression of vent, No. 1	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	(*c*)	*a*	*a*	
Lamp, examining bore, small	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Plates, No. 1 instrument, taking impression of vents, "A" large ...	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	—	*a*	*a*	
Rimers, vent, 15-inch	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Stoves, lamp (softening, gutta-percha)	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Searchers, pointed	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Scrapers { chamber (*b*) { large ...	—	—	—	—	—	—	—	—	—	*a*	—	
Scrapers { chamber (*b*) { medium ...	*a*	—	*a*	—	—	—	—	—	—	—	*a*	
Scrapers { chamber (*b*) { small ...	—	—	*a*	*a*	—	*a*	—	—	—	—	—	
Scrapers { ordnance bore, crown ...	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Scrapers { ordnance bore, half-round	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Scrapers { ordnance bore, round (pairs)	1	1	1	1	1	1	1	1	1	1	1	
Screws, for fixing scrapers	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Searchers, spring { 8-prong	*a*	*a*	*a*	—	—	—	—	—	—	*a*	*a*	
Searchers, spring { 6-prong	—	—	—	*a*	*a*	—	—	—	—	—	—	
Searchers, spring { 4-prong	—	—	—	—	—	*a*	*a*	*a*	(*c*)	—	—	
Scrapers, exterior	—	—	—	—	—	—	—	—	—	—	—	Issued according to requirements.
Tongs for grinding scrapers	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Wrench for searcher, spring	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Wrench for scrapers	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	

(*a*) Common to all; one only required, whatever the nature or number of guns to be cleaned or examined.

(*b*) Only required for ordnance having Gomer chambers.

(*c*) There is no hard brush for the 3-pr., the small Turk's head is used instead. The instrument for taking impressions is too large, a piece of wood being used; the smallest spring searcher is also too large, the pointed searcher taking its place.

NOTE.—13-inch mortars are cleaned with the same articles as 10-inch, except that the bore is scraped with old swords, instead of with the bore scrapers.

TABLE XXXVII.—TOOLS, CLEANING AND EXAMINING R.M.L. ORDNANCE.

	Guns.																			Howitzers.				Remarks.
	17·72 and 16-inch.*	12·5-inch.	12-inch of 35 tons.	12-inch of 25 tons.	11-inch.	10-inch.	9-inch.	8-inch.	7-inch.	6·6 inch.	64-pr.	40-pr.	25-pr.	16-pr.	13-pr.	9-pr.	7-pr.	80-pr.	64-pr. 58 cwt. and 71 cwt.	8-inch, 70 cwt.	8-inch, 46-cwt.	6·6-inch.	6·3-inch.	
Bits, vent, 29-inch ...	*a*	*a*	*a*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Bits, vent, 23-inch ...	—	—	—	*a*	*a*	*a*	*a*	—	—	—	—	—	—	—	—	—	—	—	—	*a*	*a*	—	—	
Bits, vent, 17-inch (*d*) ...	—	—	—	—	—	—	—	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	—	—	*a*	*a*	
Blocks, adjusting, for instrument taking impressions of Vents, No. 1 ...	—	1*	1	1	1	1	1	1	1	—	1*b*	—	—	—	—	—	—	1	1	1	1	1	1	* Mark I only.
Blocks, adjusting, for instrument taking impressions of Bore, special ...	1*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	* Special for 16-inch.
Brace, smith's (*d*) ...	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Brush, gun, piassaba, with stave ...	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Compasses, wing, 10-inch ...	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Disc, for instrument taking impression of bores ...	1*	1	1	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	* Special for 16-inch.
Gauges, vent, set of 4, 24-inch ...	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Viz.: ·22, ·25, ·275, and ·3.
Gauges, vent, set of 4, 15-inch (*d*) ...	—	—	—	—	—	—	—	—	—	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	
Gutta-percha ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	According to requirements.
Instruments, taking impressions of bores without plates, No. 1 ...	—	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	—	—	—	—	—	*a*	—	*a*	*a*	*a*	*a*	
Instruments, taking impressions of bores without plates, No. 2 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	*a*	*a*	*a*	*a*	—	*a*	—	—	—	—	
Instruments, taking impressions of bores without plates, No. 3 ...	—	—	—	—	—	—	—	—	—	—	—	—	*a*	—	—	—	—	—	—	—	—	—	—	
Instruments, taking impressions of bores without plates, Special ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Instruments, taking impressions of vents, No. 1 (*d*) ...	—	*a**	*a*	*a*	*a*	*a*	*a*	*a*	*a*	—	*a*	—	—	—	—	—	—	*a*	*a*	—	—	—	—	* Mark I.
Instruments, taking impressions of vents, No. 2 ...	—	—	—	—	—	—	—	—	—	*a*	—	*a*	*a*	*a*	*a*	*a*	*a*	—	—	*a*	*a*	*a*	*a*	

* The stores for 17·72 and 16-inch guns (unless otherwise specified) are identical.
(*a*) Common to these natures; one only required, whatever the nature or number of guns to be cleaned or examined.
(*b*) Two natures for 64-pr., viz.: one for Mark I, and one for Marks II and III.
(*d*) These stores being common with those used with S.B. or B.L. ordnance should not be again demanded by Officers if they have been already supplied for use with tools for cleaning, &c., other natures of ordnance.

TABLE XXXVII—*continued.*

	Guns.																			Howitzers.				Remarks.
	17·72 and 16-inch.*	12·5-inch.	12-inch of 35 tons.	12-inch of 25 tons.	11-inch.	10-inch.	9-inch.	8-inch.	7-inch.	6·6-inch.	64-pr.	40-pr.	25-pr.	16-pr.	13-pr.	9-pr.	7-pr.	80-pr.	64-pr. of 58 and 71 cwt.	8-inch, 70 cwt.	8-inch, 46 cwt.	6·6-inch.	6·3-inch.	
Lamp, examining bore { large / small } (d)	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	
Plates, for instruments No. 1, for taking impressions of vents { A(d) .	—	a	a	a	a	a	a	a	a	—	—	—	—	—	—	—	—	—	—	a	a	—	—	
B ...	—	—	—	—	—	—	—	—	—	a	a	a	a	a	—	a	—	—	—	—	—	a	a	
C ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	a	—	—	—	—	
Plates, for instruments for taking impressions of { bores ...	1*	1	1‡	1‡	1	1	1	1	1	—	1	c	1	1	1‡	1‡	1‡	1	1	1‡	1‡	1	1	* Special for 16-inch.
chambers	1*	1†	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	† For Mark II guns only.
Rimers, vent { 22-inch	—	a	a	a	a	a	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	‡ Common to both natures.
15-inch (d)	—	—	—	—	—	—	—	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	
Scrapers, ordnance { half-round (24-inch)	—	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	
exterior (d)	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	According to requirement.
Searcher, chisel-ended	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	
Stoves, lamp (softening, gutta-percha (d))	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	
Wrench { for check nut, for instrument, special, for taking impressions of bore	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
for clamp, for instrument, special, for taking impressions of bore	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
for discs, for instruments for taking impressions of bore	1	a	a	a	a	a	a	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

* The stores for 17·72 and 16-inch guns (unless otherwise specified) are identical.
(a) Common to these natures; one only required, whatever the nature or number of guns to be cleaned or examined.
(b) Two natures for 64-pr., viz.: one for Mark I, and one for Marks II and III.
(c) Plates are not required for 40-pr. guns, as the frame of the instrument used answers the purpose.
(d) These stores being common with those used with S.B. or B.L. ordnance should not be again demanded by Officers if they have been already supplied for use with tools for cleaning, &c., other natures of ordnance.

TABLE XXXVIII.—TOOLS, EXAMINING, CLEANING, LACQUERING, AND PAINTING B.L. GUNS.

	12-pr.	20-pr.	4"				5"		6"				8"			9·2"		10"	12"		13·5"	16·25"
			13-cwt.	22 cwt. Mark I.	Mark II.	Mark III. & IV.	Mark I.	Mark II. & III.	80-pr.	Mark II.	Mark III. & IV.	Mark V.	Mark III. & IV.	Mark V. & VI.	Mark VII.	Mark I. & II.	Mark III. IV. & V.	Mark I & II.	Mark I.	Mark III. IV. & V.	Mark I & II.	Mark I.
Bits, vent, 46-inch	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a
Bits, vent, 36 "	—	—	—	—	—	—	—	—	—	—	—	—	a	a	—	a	a	a	a	a	a	—
Bits, vent, 20 "	—	—	—	—	a	a	a	a	—	a	a	a	—	—	—	—	—	—	—	—	—	—
Brushes, piassaba, bore	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Brushes, piassaba, chamber	—	—	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Brushes, paint, ground 000	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Brushes, paint, unground 000	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Brushes, paint, sash tool No. 8	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Gauges, vent, 24-inch (set of 4)	—	—	—	—	—	—	—	—	—	a	a	a	a	a	—	a	a	a	a	a	a	a
Gauges, vent, 15-inch (set of 4)	—	—	a	—	a	a	a	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gauges, vent, 4-inch (set of 4)	a	a	—	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Holders, brush, No. 2	—	—	—	—	—	—	a	a	a	a	a	a	a	a	a	a	a	a	—	—	—	—
Holders, brush, No. 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	a	a	—
Holders, brush, No. 4	a	a	a	a	a	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Instruments, taking impression bore (with appurtenances), No. 1	—	—	—	—	—	—	—	—	a*	a	a	a*	—	—	—	—	—	—	—	—	—	—
Instruments, taking impression bore (with appurtenances), No. 2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Instruments, taking impression bore (with appurtenances), No. 3	—	a	a*	a*	a	a	a	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Instruments, taking impression bore (with appurtenances), No. 4	—	—	—	—	—	—	—	—	—	—	—	—	a*	a*	a*	a*	a*	a	a*	a*	—	—
Lamps, examining bore, large	—	—	—	—	—	—	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	—
Lamps, examining bore, small	a	a	a	a	a	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ord. B.L., rods, vent, 46-inch	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a
Ord. B.L., rods, vent, 36-inch	—	—	—	—	—	—	—	—	—	—	—	—	a	a	—	a	a	a	a	a	a	—
Ord. B.L., rods, vent, 20-inch	—	—	—	—	a	a	a	a	—	a	a	a	—	—	—	—	—	—	—	—	—	—
Scrapers, ordnance, exterior	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Searchers, pointed	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Stoves, lamp (softening gutta-percha), No. 1	a	a	a	a	a	a	a	a	a	a	a	a	—	—	—	—	—	—	—	—	—	—
Stoves, lamp (softening gutta-percha), No. 2	—	—	—	—	—	—	—	—	—	—	—	—	a	a	a	a	a	a	a	a	a	—
Tools, special:— Tools, re-coppering (in sets)	—	—	1	1	—	—	—	—	1	—	—	1	—	—	1	—	—	—	—	—	—	—

1. Special. a. Common. * With special chamber plate for each nature.

PART IV.

CHAPTER II.

PRESERVATION AND REPAIR OF ORDNANCE.

Preservation of guns.—Painting and lacquering.—Browning field guns.—Tampions.—Vent plugs.—Preserving screws.—Quantity of paint and lacquer required for each gun.—Proportion of lubricants and cleaning materials allowed for guns annually.—Operation of browning.—Stores and ingredients allowed.—Preservation of sights.—Blueing.—Bronzing.—Preservation of fittings.—Transport.—Repairs.—Reventing with copper bush.—Cone-bush.—Through-bush.—Reventing converted R.M.L. guns.—Recoppering B.L. guns.—Coppering operations for R.B.L. guns.—Refacing and renewing the breech-bush.—Refacing the vent-piece.—Fitting new copper ring.—Repair of iron bush in 7-inch gun.—Rebushing a vent-piece.—Repair of sights.—Muzzle-sight on R.M.L. gun.—Screw trunnion sight on M.L. and B.L. guns.—New leaf in a drop-trunnion sight.—Broken clamping screw.—Millar's sights on S.B. guns.—Table of painting and lacquering tools.—Venting and repairing tools.—Tools for recoppering B.L. guns.—Facing implements R.B.L. guns.—Sighting tools for S.B. ordnance.

Preservation of guns.

Paint for the exterior.

ALL ordnance forming the armament of a fortress are to be cleaned and painted biennially; but if guns mounted on the sea faces of works are found to be in a bad state from exposure to spray, or those in casemates from damp and dripping of water, they are to be cleaned and painted every year, or even more often if considered necessary by the Commanding Officer, Royal Artillery.

Lacquer for the bore.

When the exterior of a gun is painted, the bore should be coated with lacquer except in the case of guns which may be constantly required for practice, when the bore must be kept clean and well oiled.

Browning for field guns.

The smaller natures of ordnance, which in land service would be classed as field-guns, are only painted when appropriated to the sea service; for land service the exterior is browned and the interior should be kept clean with oil.

Preparation for painting.

Before painting, all rust and dry paint should be thoroughly scraped off with old swords which are supplied for this purpose; sight-notches and lines should be carefully cleaned out, and roughness if necessary removed with emery paper. The gun should then be wiped clean and left bright. Two coats of Pulford's magnetic paint are afterwards laid on, but care must be taken that the first coat is perfectly dry before the second coat is applied.

Vent-scrapers.

The vents are cleaned with vent-scrapers.

Lacquering.

Lacquer is applied to the bore by means of brushes attached to a stave; two staves are provided which are fitted with spring sockets. One is used to lacquer the sides, the other the end of bore. The lacquer can be removed from the bore in a few minutes by brushing with hot potash solution.

CHAP. II.

The gas-escape channel should always be kept clear, the outer end being merely stopped with plugs of greased tow when the guns are not in use. Gas-escape channel.

The muzzles of all rifled guns should be stopped with tampions, and those of mortars with wooden caps, to keep out moisture and rain. Tampions.

Vent-plugs are used with mounted guns for the same reason. Vent-plugs.

Whether mounted or lying on skidding, guns should always be left depressed at the muzzle to prevent water from lodging in the bore.

When guns fitted for L.S. have the friction-tube-pin holes, and the guide-plate hole filled by preserving screws, it is desirable that these screws should be removed occasionally to prevent them from becoming fixed in by rust. Preserving screws.

Quantities of Paint and Lacquer Authorised for Rifled Ordnance.

Description.				Quantities of Pulford's paint for each coat. lbs.	Pulford's paint for each coat. oz.	Lacquer for bores, one coat. oz.
Ordnance ..	R.M.L.	Guns ..	17·72-inch			
			16 "			
			12·5 "	4	12	14
			12 " 35 tons ..	4	8	13
			12 " 25 " ..	3	4	12
			11 "	3	4	11
			10 "	2	12	9
			9 "	2	0	8
			8 "	1	8	8
			7 " 6½ & 7 tons	1	0	6
			7 " 90 cwt. ..	1	0	5
			6·6 "	..		..
			64-pr. 64 cwt. ..	1	0	4
			40 "		14	4
			25 "		12	3
		Converted	80 "	1	4	8
			64 " 58 & 71 cwt. ..	1	2	6
		Howitzers	8-inch 70 cwt. ..	..		..
			8 " 46 " ..		14	5
			6·6-inch	..		..
			6·3 "		12	4
	R.B.L...	.. ..	7 " 82 cwt. ..	1	8	6
			7 " 72 " ..	1	8	5
			40-pr. 35 & 32 cwt. ..		8	4
			20 " 16 cwt. ..		6	4
	B.L. ..	.. ..	12-inch, 43 tons ..			
			10 "			
			9·2-inch			
			8 "			
			6 "			
			5 "			
			4 " 22 cwt. ..			
			4 " 13 " ..			

CHAP. II.

QUANTITIES OF PAINT AND LACQUER AUTHORISED FOR S.B. ORDNANCE.

Description.					Quantities of Paint, each coat. lb	Quantities of Paint, each coat. oz.	Quantities of Lacquer, one coat. oz.
Ordnance, cast-iron, smooth-bore.	Carronades	32-pr.,		17 cwt.		6	3
		24 ,,		18 ,,		6	3
	Guns	8-in.		65 ,,	1	0	6
				60 ,,	1	0	6
				54 ,,		14	5
		68-prs.		112 ,,	1	8	10
				95 ,,	1	4	8
		42 ,,		84 ,,	1	4	6
				67 ,,	1	4	6
		32 ,,		63 ,,	1	2	6
				58 ,,	1	2	6
				56 ,,	1	2	6
				50 ,,	1	0	6
				48 or 50 cwt.	1	0	5
				45 cwt.	1	0	5
				*42 ,,		12	5
				40 ,,		12	5
				39 ,,		12	5
				32 ,,		10	4
				25 ,,		8	4
		24 ,,		50 ,,	1	0	4
				48 ,,	1	0	4
				20 ,,		8	3
		18 ,,		42 ,,		12	4
				38 ,,		12	4
		12 ,,		34 ,,		12	3
				33 ,,		12	3
		9 ,,		28 ,,		10	3
				24 ,,		8	2
		6 ,,		17 ,,		6	2
	Howitzers	10-in.		42 ,,		12	3
		8 ,,		22 ,,		8	3
	Mortars	13 ,,	S.S.	100 cwt.	1	4	6
				81 ,,	1	0	6
			L.S.	36 ,,		12	3
		10 ,,	S.S.	52 ,,	1	0	4
			L.S.	18 ,,		8	3
		8 ,,	L.S.	9 ,,		6	2

* This applies also to the 32-pr. S.B. B.L. gun.

The following are the proportions of lubricants and cleaning materials allowed annually for the preservation of guns when mounted:—

TABLE XXXIX.

Stores for the Preservation of Armaments.

Articles.	Purpose.	Rifled Ordnance. Proportions. Open Works.	Rifled Ordnance. Proportions. Casemates.	Rifled Ordnance. Natures.	Smooth-Bore Ordnance. Proportions.	Remarks.
Bricks, bath ...	General use...	*1 to 5 guns.		M.L. and B.L.	*1 to 20 pieces.	
Cloths, sponge...	General use...	*3 per gun.		M.L. and B.L.	*1 to 10. „	
Field's grease, No. 3†	For coating bright parts ...	*1 lb. per gun.		7-inch B.L.	—	Exclusive of guns in use for drill.
		*½ „ „		40-pr. and 20-pr. B.L. ...	—	
		*6 oz. „		12-pr. B.L. and under ...	—	
		*2¼ lb. „		All heavy guns on W.I. carriages and platforms ...	—	
		*1 lb. „		All medium guns on W.I. carriages and platforms ...	—	
	For teeth of cog-wheels ...	7 lb. per gun.	4 lb. per gun.	12·5-inch and 12-inch, 35 tons ...	—	
		6 „ „	3 „ „	12-inch, 25 tons, to 10-inch ...	—	
		5 „ „	3 „ „	9-inch, on traversing platforms..	—	
		6 „ „	—	9-inch, on Moncrieff carriages ...	—	
		3 „ „	—	7-inch, on Moncrieff carriages, M.L. and B.L.	—	
	For teeth of gear of turntables...	—	2 cwt. per gun.	Guns mounted on turntables ...	—	
Hemp, undressed	For cleaning the bore	*3 lb. per gun.		B.L.	—	
	General use with the turntables...	*28 „ „		Guns mounted on turntables ...	—	
Linen, old ...	General use..	*2 lb. to 5 guns.		M.L. and B.L.	*1 lb. to 10 pieces.	
Oakum	General use..	*1 „ „		M.L. and B.L.	*1 „ 20 „	
Oil, Rangoon† ...	For lubricating the axles and bearings of the trucks and rollers, and also the shafts and bearings connected with the elevating and traversing gears (25 per cent. more allowed at Halifax, N.S.)	4 quarts per gun.	3 quarts per gun.	12·5-inch and 12-inch, 35 tons ...	—	These quantities will also suffice for loading stages.
		3 „ „	2 „ „	12 inch, 25 tons, to 10-inch ...	—	
		2 „ „	1½ „ „	9-inch	—	
		1 quart per gun.		7-inch M.L.	—	
		1 pint „		Lighter natures on traversing platforms	1 pint per gun on traversing platforms	
	For lubricating bearings of turntables	—	20 galls. per gun.	Guns mounted on turntables ...	—	
	For cleaning and preserving bright parts, &c.	1½ pints per gun.	1 pint „	Heavy M.L.	*1 pint to 10 pieces.	
		1 pint „	—	Medium M.L.	—	
		1 quart per gun.		B.L.	—	When guns are in use for drill.
		*1 pint „		B.L.	—	When guns are not in use for drill.
Soap, soft	General use...	*2 lbs. to 5 guns.		M.L. and B.L.	*1 lb. to 10 pieces.	
Turpentine, spirits of	For turntables to clean off oil when set	—	2 galls. per gun.	Guns mounted on turntables ...	—	

* Half of these proportions will be allowed for cleaning and preserving guns, carriages, platforms, &c., in R.A. charge, ordered to be kept dismantled in time of peace.

† Field's grease and Rangoon oil have been substituted for composition (cocoanut oil and chalk), Lucca, mineral, and sweet oils. The remaining stock of these lubricants will, however, be used up.

CHAP. II.

Should emery or other articles not mentioned in this list be required in certain cases, they will be supplied to Officers Commanding Royal Artillery on special demand, the purpose for which they are required being clearly stated in the requisition. Woollen rags and dressed flax will not be allowed.

Officers in command of Royal Artillery districts may also demand, on the receipt from store of rifled M.L. or B.L. guns requiring to be specially cleaned and lubricated when first mounted on the defences, an additional supply of bath bricks, grease, hemp, and oil, in such quantities as may be absolutely requisite, not exceeding one-half the annual proportion. Less than one bath brick need not be demanded.

In certain positions, such as those at the sea batteries at Portsmouth, where the armament is much exposed, the annual proportions of grease and oil may be increased 10 per cent.

Browning.

Operation of browning.

The operation of browning, which is applied to all guns for field service may be described briefly as follows:—

The guns may be placed on two trestles, resting only on wood pieces in the bore, or on the cascable in the case of muzzle-loading guns. A warm workshop is required for this operation because browning cannot be done in the open air, for fear of frost and dust.

First, all sights and fittings must be carefully removed, and the holes and sockets tightly plugged up with wood. This is necessary to keep the grease from exuding from the screw-threads and holes, which would spread over the surface of the gun and prevent the browning mixture from acting on the metal. The operations may then be described in the following order:—

(1) The gun may be steamed for 10 hours; but if there are no appliances for steam it may be washed with boiling water, and raised to nearly the same temperature by pouring cans of boiling water upon it; after this it must be washed with a lye of potash (1 lb. of black American potash to 1 gallon of water) until the grease is thoroughly removed. The object so far is to get rid of all greasy matter and oil which may remain on the surface of the metal; hence the water should be as hot as the operator can use, who ought to rub vigorously all over the surface with a clean hard brush; a little hard soap may be used, and the water should be frequently changed. This scrubbing must generally be repeated several times, including the application of potash; in fact it must be continued until perfect cleanness and freedom from grease is ensured. Care must also be taken not to touch the gun with any fatty matter, or even with the hands, for it may take hours of washing again to wholly remove the effect.

(2) While warm wash with hydrochloric acid and water (equal parts if the acid is of full strength) to remove all old browning and oxide; then wash with clean water, and thoroughly dry. This should leave the metal quite white.

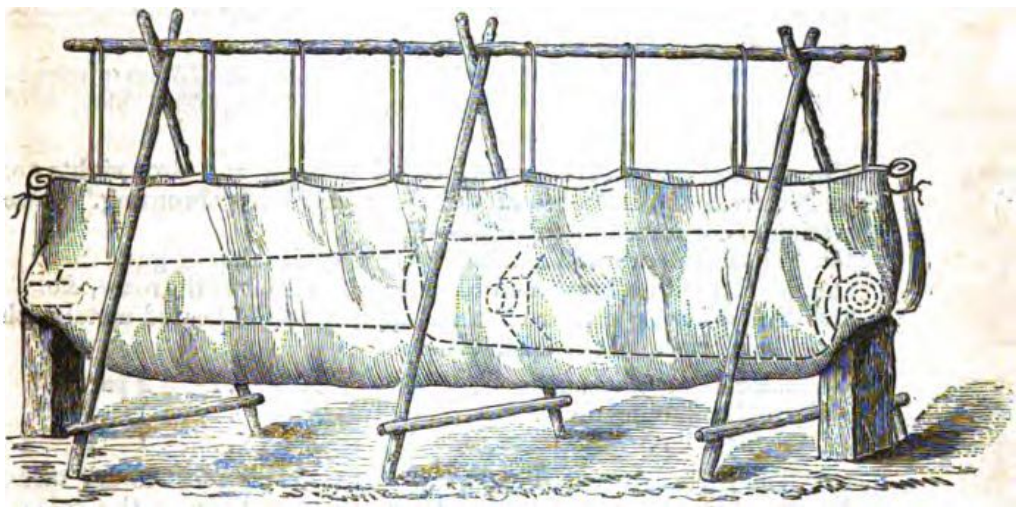
(3) When the gun is quite cold apply the browning mixture with a sponge on the end of a stick; let it stand for 12 hours, in the ordinary temperature of the summer months; then rub off the rust with fine scratch-card and brush. The browning mixture is composed of the following ingredients:—

Tincture of steel	2	parts.
Nitric acid..	1	„
Blue vitriol	1	„
Spirits of nitre	1½	„
Spirits of wine	1½	„
Soft water	32	„

CHAP. II.

(4) Apply the mixture as before, let it stand about six hours, then rub off the rust. Repeat the operation six times, or more frequently if not perfectly successful each time.

(5) As soon as the mixture has taken sufficient hold on the surface, the piece must be scalded with boiling water. If no tank is available a canvas hammock can be prepared by artificers in the manner shown by the accompanying sketch, taking care that there is sufficient room between the canvas and the gun to allow a good volume of water to lie in contact with every part. A good supply of boiling water must be provided, and there must be no serious check in the flow. Let stand for 15 or 20 minutes, and use the water then to take the chill off the next gun before scalding.



(6) Lastly, when rubbed clean and dry, and carded almost to a polish, the gun should receive a coating of olive oil.

The colour of the browning will mainly depend on sufficient application of the mixture, good carding, and *thorough scalding* of the gun before the olive oil is put on.

Care must be taken to sponge out and dry the bore well after each operation of steaming, boiling, or washing.

Stores and ingredients for browning.

The following is a detail of the stores and ingredients allowed biennially for browning six 9-pr. or four 16-pr. R.M.L. guns:—

Acid, nitric	oz.	2	To be mixed in two quarts of soft water.
Nitre, spirits of	„	2	
Steel, tincture of	„	4	
Vitriol, blue	„	2	
Wine, methylated spirits of	„	3	
Acid, hydrochloric	lb.	6	To be purchased locally.
Brush, shoe, hard		1	
Card, scratch, on leather*	ins.	18	
Cloth, emery, fine	sheets	6	
Cloths, sponge		6	
Coal	cwt.	6	
Oil, Lucca	gill	½	
Pail, wood, water, barrack*		1	
Pan, earthenware, 6 quarts		1	
Potash, American	lb.	1	
Soap, hard	„	1	
Sponge, water, ¾ oz.*		1	
Strip, iron, browned to pattern tint*		6	

* Articles marked thus * will be returned to store on completion of process.

CHAP. II.

Preservation of Sights.

Preservation of sights.

Steel tangent bars, trunnion sights, and all trunnion sight leaves are "blued."

Blueing.

Blueing consists simply in covering the surface with a thin film of oxide sufficient to give the article a deep blue colour, and to prevent further oxidation from exposure to the atmosphere. This is easily effected by well polishing the surface of the article, and heating it to about 580° when it assumes a blue colour, and then allowing it to cool gradually. A sand bath is generally used in order to obtain a uniform heat; the bar or sight is taken out from time to time to watch the change of colour and to prevent its going too far. The temperature may be judged by the colours which successively appear on the surface of the steel at various temperatures, viz:—

At 450° Fahr. the steel becomes a straw colour, at 475° an orange or gold, 500° brown, 530° purple, 550° violet, 580° blue, 610° white, and at 625° red.

Bronzing.

The exposed gun-metal portions of all tangent and drop sights are protected from the influence of the atmosphere by "bronzing." The operation is conducted as follows:—

1st. Polish the part well and heat over a spirit lamp or gas.

2nd. Polish with a brush and blacklead, to remove all grease, &c.

3rd. The bronzing mixture is then applied to the heated metal with a camel hair brush. It consists of—

Bichloride of platinum	2 parts.
Corrosive sublimate	1 "
Vinegar	1 "

4th. The parts are next dipped into boxwood sawdust to dry them, and then again polished with blacklead to give a body to the colour. The figures and bright portions are now marked out with a file or emery cloth, and the whole is finally varnished with shellac and methylated spirits applied while the article is hot.

Preservation of Fittings.

Preservation of fittings.

The breech-screw and bright parts of all breech-loading guns, either in store or when rarely used, will be coated with a lubricant consisting of white lead and tallow.*

When R.B.L. guns are not in use, the vent-piece and all the breech fittings except the breech-screw itself should be removed and laid by in store.

Transport.

Transport.

In preparing ordnance for transport, the breech fittings, sights, pivot pieces, elevating plates, friction tube pins, and, in fact, anything which would project beyond the surface of the gun, and be liable to injury during transport, should be removed, and the holes filled either with preserving screws, or with plugs of tow and tallow.

For land transport the smaller natures of guns are packed in jute bags

* White lead 1 lb., Russian tallow 4 lb. In hot climates the proportion of white lead should be increased. The materials must be thoroughly mixed while warm. A little sperm oil may be added when this composition is used instead of lacquer in the bore, or whenever it is required thinner than the usual mixture.

To face page 343.

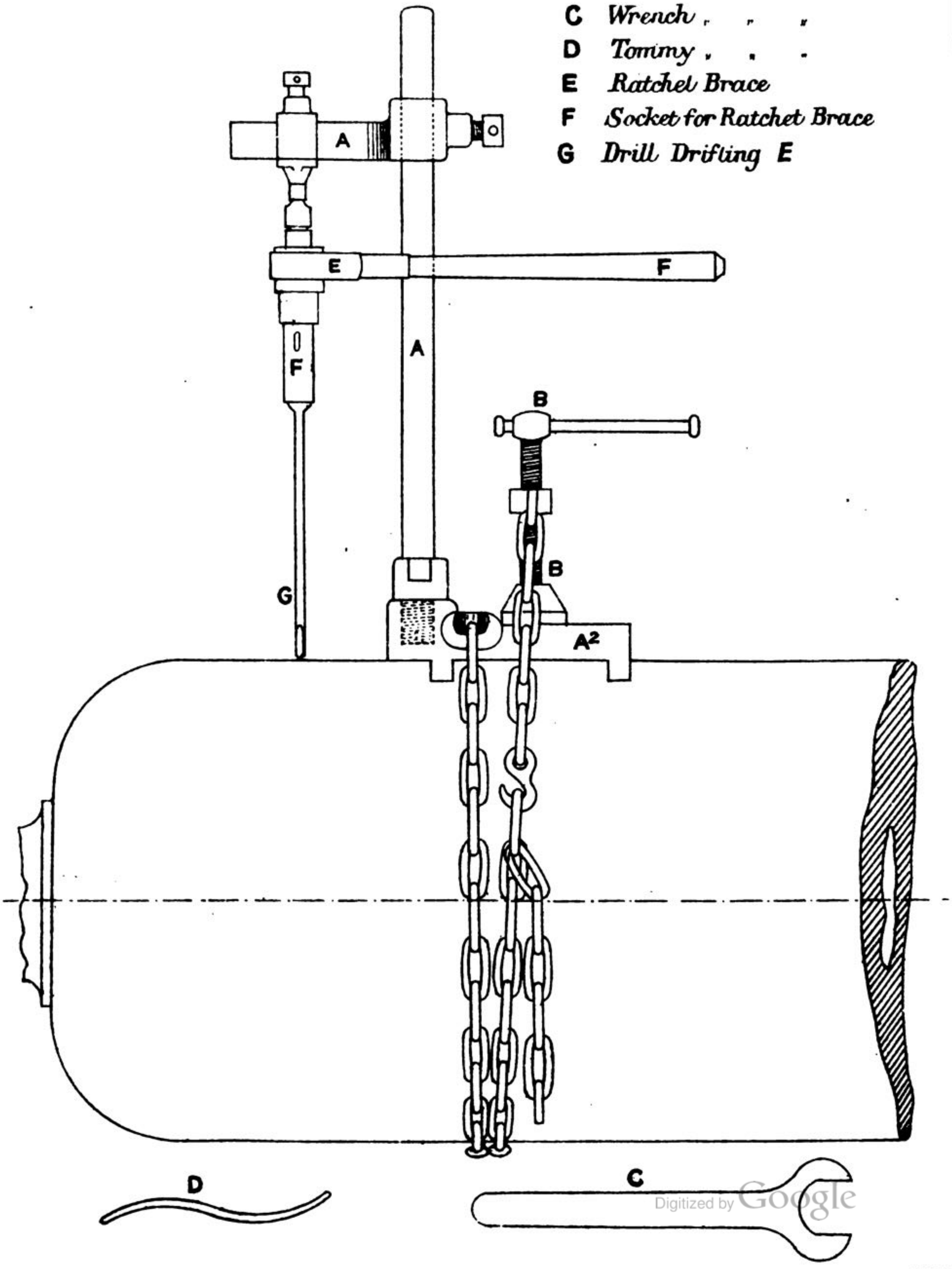
Plate A.

SKETCH SHEWING DRILL POST AND RATCHET BRACE IN POSITION ON A 64 PR. 64 CWT. R.M.L. GUN.

SCALE $\frac{1}{8}$.

References.–

- A *Drill Post* { A¹ *Cross-head*, A² *Foot plate* }
- B *Clamp for Drill Post*
- C *Wrench* „ „ „
- D *Tommy* „ „ „
- E *Ratchet Brace*
- F *Socket for Ratchet Brace*
- G *Drill Drifting* E



and for sea transport in boxes. Guns above 16-prs., however, have no such protection.

R.B.L. guns are issued, and may be transported about with the screw in the gun; all other parts being removed and packed in a box.

B.L. guns at first had the breech-block as well as the fittings removed except in the case of the 4-inch and smaller natures of this type of gun, but the breech-block is now generally secured in the gun. The bore is closed with a disc or cylinder of wood set in grease composition; these plugs should be left in the gun until mounted, even then they may often be useful to keep out the weather if the gun is not required for firing. They can easily be prised out with a chisel.

R.M.L. axially vented, *vide* p. 162. Cascable and counterbalance.

Repairs.

Minor repairs.

Whenever the examination of a gun should involve any repair, or when the sights and fittings get damaged in the field, it is desirable that the work should if possible be carried out on the spot; but there are many repairs which can only be performed at certain stations, or in the Royal Gun Factory. In this chapter it is only intended to explain such repairs as a qualified regimental artificer ought to be capable of executing under the supervision of an officer or an Inspector of Warlike Stores.

Reventing R.M.L. or S.B. guns.

Reventing with copper bush.

Within the United Kingdom, reventing is performed by artificers sent out from the Royal Gun Factory, who make a tour of each district in the course of a year, except the southern and south-western districts, which are served by artificers from the Gun-wharf at Portsmouth or Plymouth respectively. Abroad, certain stations and ships are provided with sets of reventing tools, and the work would be carried out under the direction of a Firemaster Royal Artillery or Gunnery Lieutenant R.N., holding a certificate for this purpose.

The operation of drilling out the old bush must be very carefully performed, for instances have occurred of the screw-thread being seriously damaged, and in some cases the drill has been allowed to run so far untrue as to render a special bush necessary.

The following instructions have been prepared.

Drilling out copper bush.

The gun having been conveniently levelled on the carriage, a piece of canvas is placed on the breech of the gun, and the drill-post is then placed upon it (Plate A). The object of the canvas is to prevent the gun being marked or bruised, and to keep the drill-post from slipping.

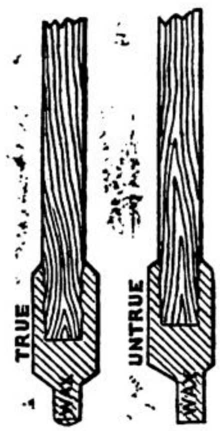
The wire, directing, is then passed down the vent channel and the screw of the drill-post adjusted directly over it. The drill-post is then made fast by passing the chain round the gun, fixing it to the base of the drill-post, and then firmly tightening it by means of the attached screw clamp.

The drill, drifting, E (Plate B) is then placed in the ratchet brace and the point of the drill into the vent. The screw in drill-post is turned down on to the point of the screw in the ratchet brace, and then the process of drilling out can commence. The drill should be taken out after each inch of drilling, the cuttings removed with a piece of bent wire, and the hole cleaned out with tow; after which an impression should be taken with wax to ascertain if the drill is cutting correctly.*

* It is well to examine the cuttings to see that they consist solely of copper.

CHAP. II.

To do this a piece of wax composition* should be worked on the end of a stick sufficiently small to pass down the hole. On being pressed hard against the bottom of the hole and removed, it will show whether the channel is concentric with the direction of drilling; should it be more on one side than the other (*see* sketch) the drill must be moved, the top being shifted towards the side with the broadest chamfre.



The drills, drifting, are of different lengths to suit the depths of bush in different guns and should always be passed entirely through the copper into the bore, to loosen the cone at the bottom.

The drill-post and chain are then removed from the gun, and the hole squared at the top, as follows:—

Drive the drift F (Plate B) a little way down to mark the angles for squaring, and with a chisel (hand-graver's) cut away the metal at each mark until the hole is squared.

Drive the shortest drift in with a hammer and unscrew the bush; it frequently happens that it comes out in pieces, to meet which case longer drifts are supplied, but the top of the hole must be squared every time.

There are times when the bush is so tight that the drift cuts the hole round without unscrewing the bush; it is then necessary to erect the drilling machine again, and to put the drill, tapping B, down as far as the top of the cone. The remainder of the thread of the bush can then be removed by screwing down the tap C_5 (Plate B), and working it backwards and forwards on going down. The cone portion can be removed by gently hammering the drift F (Plate B) into it and lifting up the shell of the cone.

In all cases the tap C_5 is passed down to clear the thread, but care must be taken not to drive it hard against the top of cone.

The cone-rimer H (Plate B) is now passed down to remove the burrs, gently turning the wrench.

The hole is then cleaned out with tow.

Before the insertion of a new bush it is necessary to observe the pitch of the thread on the old one. Some converted R.M.L. guns and many S.B. pieces were originally prepared for a bush with 6 threads to the inch, and all these must be revented with bushes of similar pattern. As a rule, however, the hole will be found tapped for a bush of 7 threads to the inch. By comparing a piece of the old bush with a new one, the nature of thread can be recognised.

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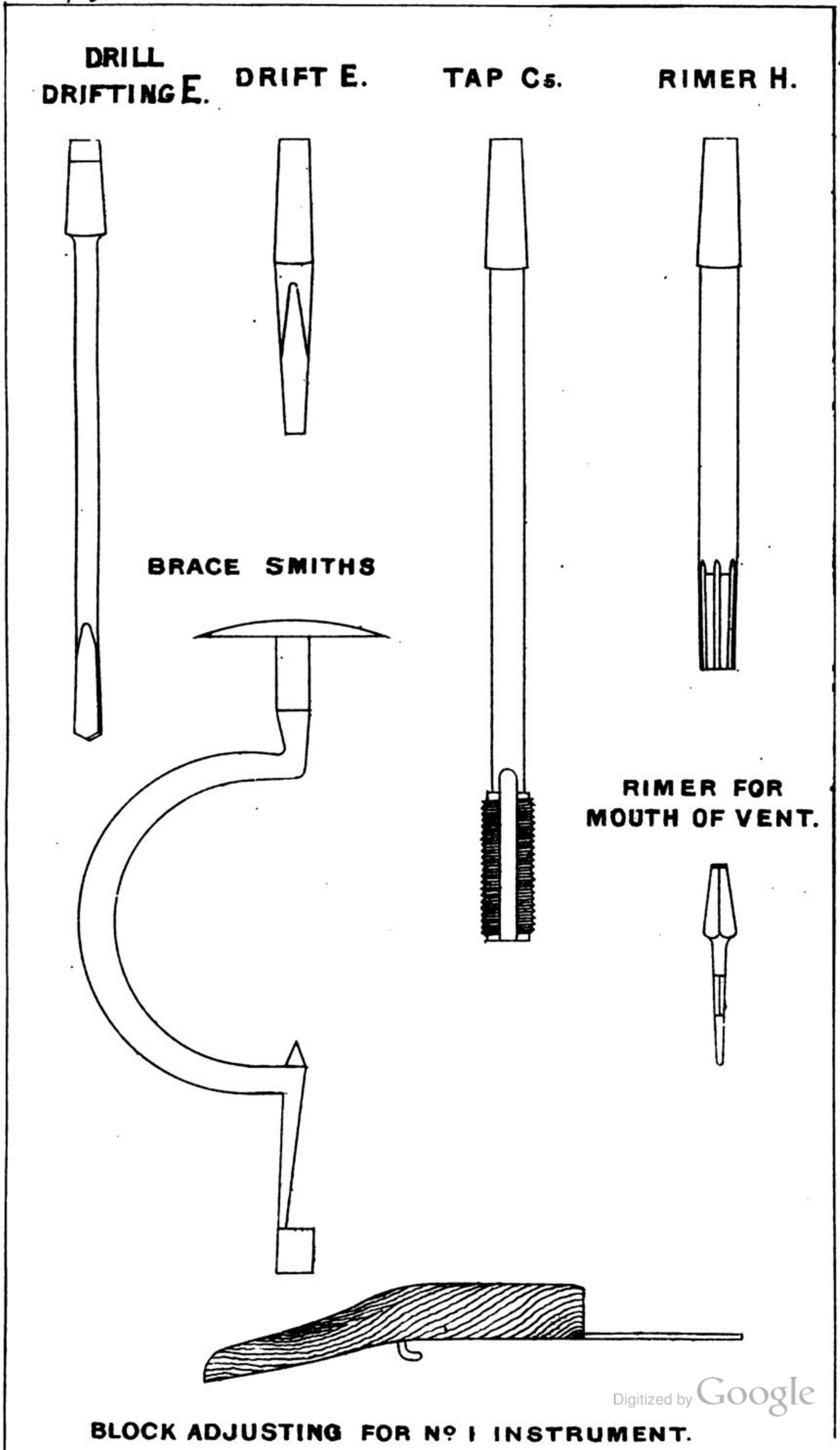
* Beeswax 2 parts, treacle 1 part, soft soap 1 part.

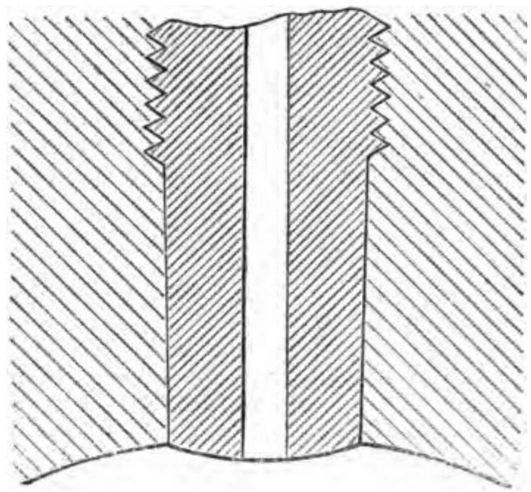

DRILL DRIFTING E.
DRIFT E.
TAP C5.
RIMER H.
BRACE SMITHS
RIMER FOR MOUTH OF VENT.
BLOCK ADJUSTING FOR No. 1 INSTRUMENT.

Cone Bush.

Cone bush.

A cone bush will invariably be put in if possible. The new bush is screwed tightly down, and a gutta-percha impression is taken in the bore to ascertain the amount projecting within.

The position being marked on the top of the vent, the bush is taken out, cut to length and filed round, leaving the cone to project very slightly, front and rear, as shown in the sketch.

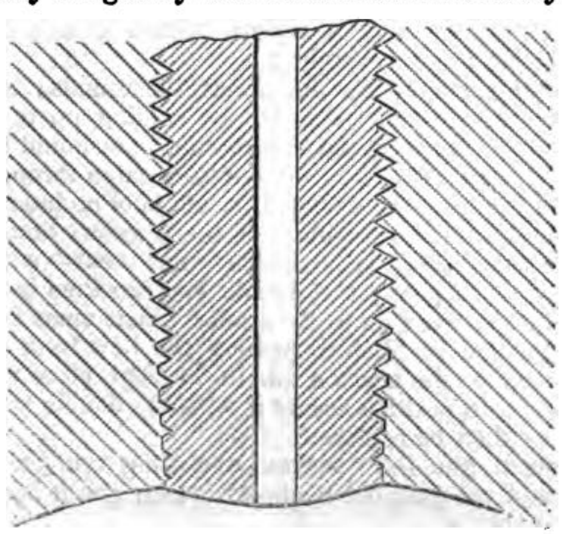


The bush is again screwed tightly down in its place and another impression taken; if correct, the top is cut off and finished. The vent is then rimed out by means of the armourer's brace (Plate B) with the rimer to allow the vent gauge ·22-inch to pass down. If the gun is for sea service the top of the vent must be opened with a special rimer which forms a cone to the depth of an inch. The operation completed by stamping an the top the letter H, to indicate that the material consists of hardened copper.

With a Through Bush.

Through bush.

The principle of through-bushing a gun is to tap or screw the hole through, thereby doing away with the cone almost entirely and continu-



CHAP. II.

ing the thread into the gun, taking care however that the bottom of the hole is rather less in diameter than the top in order to enable the vent-bush to be tightly gripped.

The copper bush having been screwed in and removed, as in the operation of cone-bushing, the cone-rimer H is passed through to make the hole the right size for tapping. The depth of the hole is then measured and marked with chalk on the tap C_3, which is gently worked down until the point of the tap is level with the bore of the gun.

The hole is now well cleaned out with tow. Then the through bush having been rounded at the end, and the proper depth marked upon it with chalk, is screwed down; care being taken not to put too much force on the wrench, which might cause the copper to break.

An impression is next taken to ascertain if the bush be through. If not, a quarter of a turn at the wrench is taken at a time until it is found correct. Should the bush be too far through it must be taken out, the surplus metal filed off to a new button-head, and then re-adjusted.

The upper end of the bush is now cut off, and the top finished in the usual manner; the vent is rimed out to allow the ·22-inch gauge to pass down, the bush is prepared for sea service if necessary, and finally it is stamped with the letter H.

Removable radial vent-bush for 64-pr. R.M.L. Mark III S.S.

The bush is made wholly of steel, a gas-tight joint being obtained by means of a shallow mushroom head to the bush, and a thin disc of copper intervening between the head of the vent-bush and the metal of the gun. The vent-bush is made in two lengths, the lower half (C) being inserted from the interior of the bore by the aid of a special instrument. A double key ring is then passed down the hole, one feather of which fits into a feather-way in the metal of the gun and the other into the bush, and thus prevents the lower half of the bush (C) from turning in the gun. The lower bush has to be held in position until it is screwed tightly up by means of a spanner applied to the hexagon (E) on the upper bush (D), a small copper disc having been previously placed in the top of the lower half, a hollow plug (F) in the upper portion is then screwed tightly down on to the disc, thereby sealing the joint at the junction of the two parts.

In order that the service quill friction tubes may be used, a block (G) is secured to the gun by two fixing screws, into which the "pin friction tube" is screwed.

The part which will probably be first affected by the action of the gas will be the middle joint of the two bushes, and if the escape of gas at this point is not of a serious nature it may be rectified by screwing the plug (F) down tighter.

The vent will probably last for about 100 rounds; but it should be taken out occasionally and examined by holding up to the light, and if it is found to be much eaten away another one should be substituted; but should the metal of the bush have been eaten through and the gas have corroded the gun, the defect, if small, is of no importance.

Reventing 12·5-inch Mark II 16-inch and 17·72-inch R.M.L. guns.

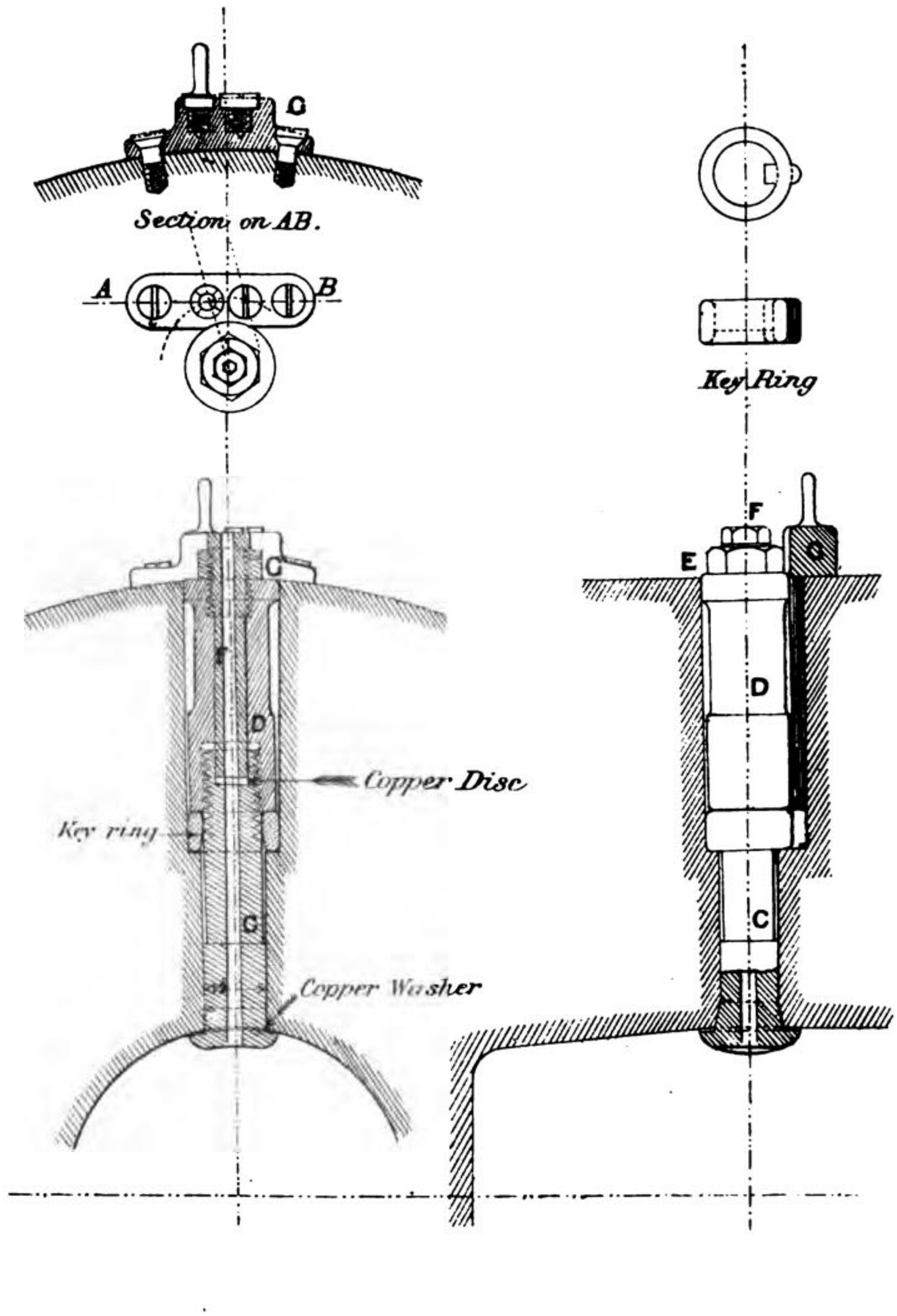
To remove the axial vent-bush of these guns: take off the socket "supporting vent-bush," remove the "nut vent" with the wrench supplied for this purpose; the double key can then be taken out and the bush pushed forward on to the cradle which must be passed down the bore to receive it. Before passing the new bush down the bore insert the shank of the acorn guide in the vent, place the bush on the cradle and when in position secure it with the double key and nut, and the socket may then be replaced.

In the 16-inch gun the "socket supporting vent-bush" is attached to the breech of the gun, but in the 12·5-inch gun it is attached to the interior of the shutter.

To face page 346.

REMOVABLE RADIAL VENT BUSH FOR 64 Pr. R.M.L GUNS (MARK III) SEA SERVICE.

Scale 1/4



Converted Guns.

S.B. guns converted to rifled guns on the Palliser system are bushed in a special manner, viz., by using a through bush of sufficient length to project into the bore, and by upsetting the projecting end into a countersunk recess prepared in the gun. **Reventing converted guns.**

The old bush is drilled out as already explained, arranging the drill-post, however, in this case at the angle of inclination of the vent. In removing the shell of the bush, the last piece should be unscrewed and allowed to drop into the bore.

Special bushes are supplied for these guns, but a common through bush, 12·5 inches in length will answer equally well if the screw-thread is turned off at the point for about a quarter of an inch: the bush is screwed in by hand and by means of a lever wrench. To insure that only the required amount projects into the bore, a "*block stop for vent*" is passed into the chamber. This is an iron block attached to a bar, and having a portion slotted away of the depth sufficient for the projecting part of the bush to fit into; the bar is kept in centre of the bore by means of two wood discs. **List of tools, p. 360.**

When the end of the bush comes in contact with the bottom of the slot on the stop-block, the operation of screwing is discontinued, and the projecting copper "upset" into the recess as follows.

A split head or "*expanding block*" of wrought iron, fitting the shape of the chamber, is pushed into the latter by means of an instrument called an "*extracting hook*" which is used for extraction afterwards; into that part of the block immediately under the bush a piece of hard steel is dovetailed. An iron tube called a "*guide cylinder*" (the inner end of which fits over the expanding block) is next passed up the bore, and through this guiding tube is passed a solid iron *wedge*, which being forced into the expanding block presses out the sides of the latter, and so sets up the copper into the recess in the cup. The wedge is attached to a stout iron bar, the outer end of which is struck by a "*hammer-monkey*," slung from a 10-foot iron gyn placed in front of the muzzle and worked by two or three men, as a considerable amount of power is required for setting up of the bush of hardened copper.

To keep the bar to which the wedge is attached in the centre of the bore it passes through a "*wood collar*," and also through the centre of a "*cross-bar*" in front of the muzzle, which is retained in position by a frame consisting of two rods with loops fitting over the trunnions and secured by nuts and screws to the ends of the collar.

When the copper is sufficiently "set up," the bars are loosed from the collar, and the latter removed. The wedge and cylinder guide are then withdrawn and the expanding block removed by the hook, after which a gutta-percha impression is taken of the bottom of the vent to ascertain if the operation has been performed correctly; in that case the copper should still project into the bore for about 0·05-inch.

Instructions for Re-coppering B.L. Guns with Cup Obturation.*

Removal of the old Copper Ring.

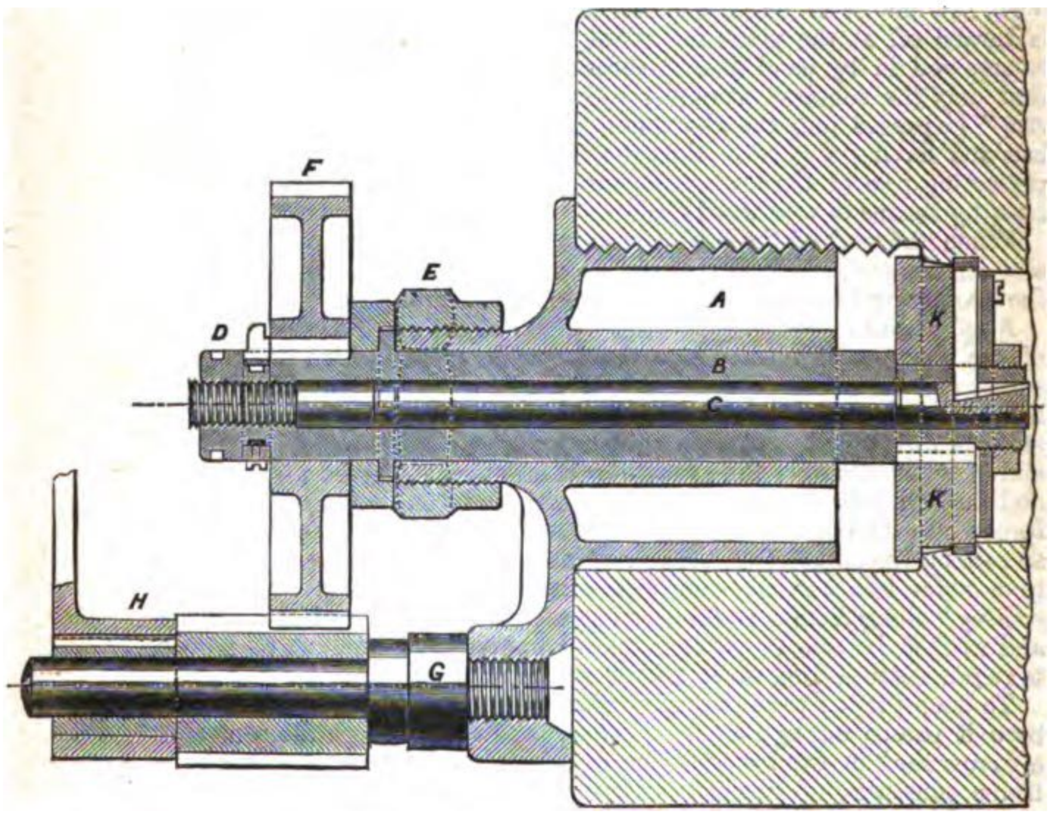
A gun-metal guide (A), similar to the breech-screw, is placed in the gun. A hollow spindle (B) passes through the centre, carrying on its end a steel block (K) of a little less diameter than the bore of the gun. A slot is cut in this block, in which is placed the cutter (cutting out old copper No. 1 or 2). The depth of cut is regulated by a **Re-coppering B.L. guns.**

* For list of tools issued for each nature, see p. 364.

CHAP. II. feed spindle (C) passing through the hollow spindle, having an undercut inclined plane on that portion in contact with the base of the tool, and a screw-thread on it sother end. Over the screwed part works a capstan head (D), by turning which the spindle can be either advanced or withdrawn, the cutter being compelled to follow the inclined plane by reason of its base being fixed by the undercut slot.

The feed motion for the *boring blocks* is given by the hexagonal nut (E).

FIG. I.—(CUTTING OUT OLD COPPER RING.)

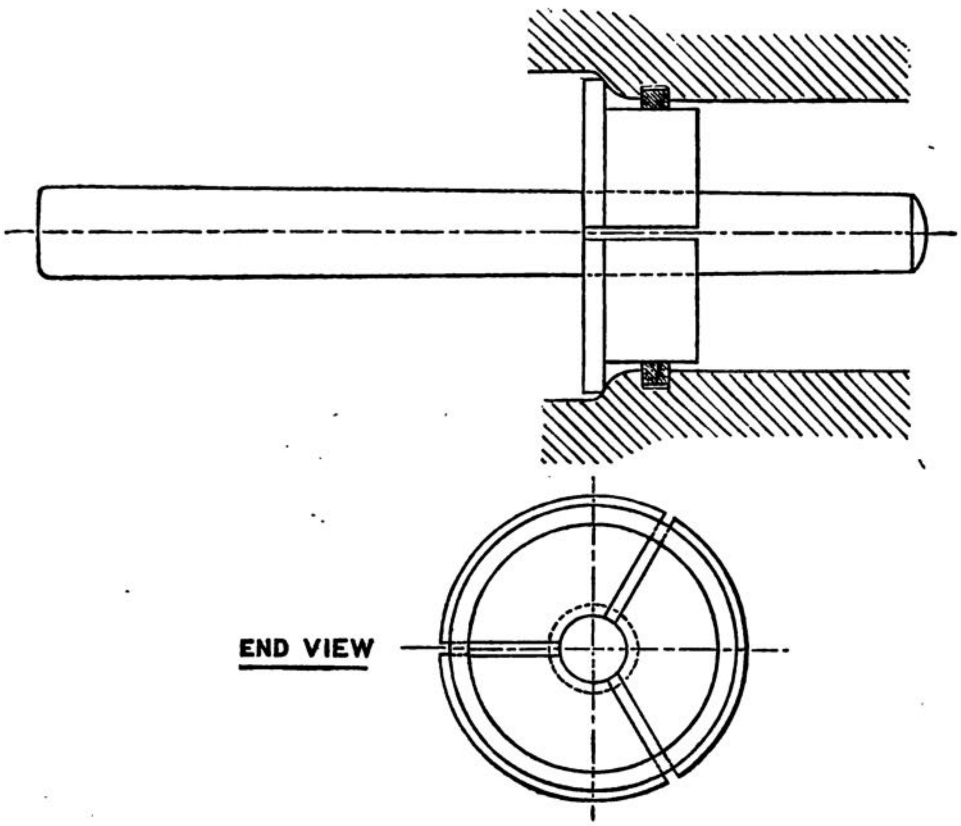


A toothed wheel (F) is fixed to the outer end of the hollow spindle. On the base of the guide block a bracket is cast, to which is screwed the pinion shaft (G). A pinion with handle (H) in placed on this shaft, and gears with the toothed wheel. The guide block having been placed in the gun, the block with its cutter is brought immediately under the copper ring, when the nut (E) is screwed home—if there is any feed on this nut the gun will be damaged. The pinion is shipped on the bracket and the toothed wheels brought into gear. On turning the handle, the block and tool revolve, and the copper is cut by the feed D. The cutter first employed is only half the width of the copper ring; after half the ring is cut through, the tool is changed for one the same width as the copper. After the second tool has cut through the ring only the copper shell is left in the gun, and this must be carefully removed by the aid of a piece of metal bent to a convenient form to prise the ring out with. A slot is cut in the "block guide" to allow water mixed with a little soft soap to be injected with a syringe to make the copper cut freely and prevent tearing.

Placing the New Ring.

The new ring which fits loosely is now placed in the vacant groove. In order to set it up and make it fit tightly a broad circular block (expanding No. 2 in three parts), composed of three segments, and having a tapered hole in its centre, is placed inside the copper. Into the hole in the centre of the segments is placed a drift (for block expanding No. 2) and smartly struck with a sledge hammer: this forces the segments outwards and presses the new copper ring into the groove.

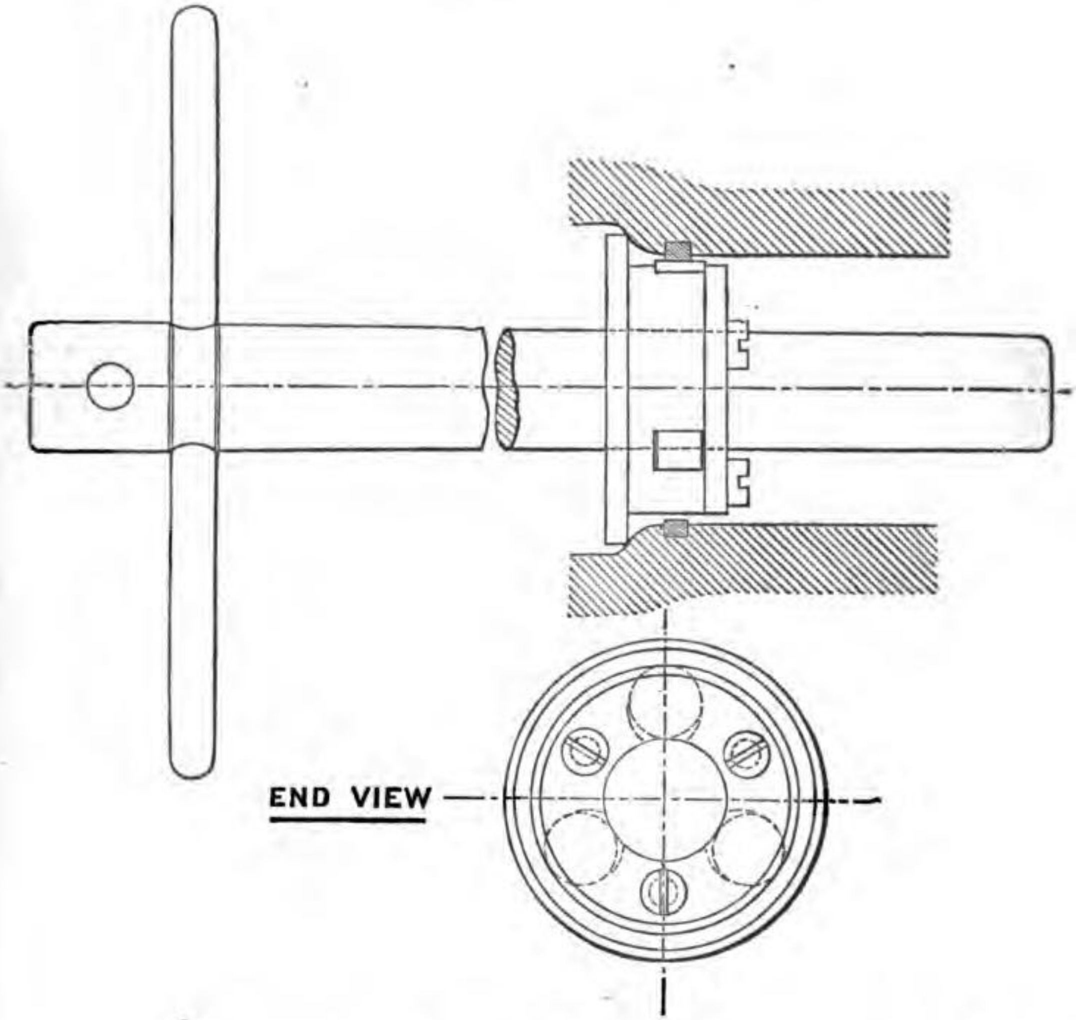
FIG. II.—(FORCING NEW RING INTO GROOVE.)



The segmental block is now removed, and a roller block (No. 3) of the following construction is put its place. This roller block has a tapered hole in its centre, and carries in recesses in the annular portion three steel wheels, having a large outward and inward play on their axles; these wheels project beyond the circumference of the disc, and also into the tapered hole through the centre. A tapered spindle (for block roller No. 3) is driven hard into the central hole, and the steel wheels are consequently set out against the copper ring. A lever is now put through a hole in the outer end of the spindle which is turned for about 10 minutes, being kept tightly in the while by hammering; this further forces the copper into the groove. To remove the tapered spindle it should first be loosened by striking it sideways with a hammer or mallet.

CHAP. II.

FIG. III.—(EXPANDING NEW RING.)



The roller block is now removed, and the boring up of the ring commenced (Fig. IV). The guide is again inserted, but the former cutter block is now replaced by the boring blocks 4, 5, and 6, in succession, which are fed up by the nut (E). (Fig. 1). When the ring has been bored up to within a few thousandths of an inch of its finished dimensions by means of the block (before proof, boring, No. 5), the gun is fitted with the breech screw with an obturator cup of slightly smaller dimensions than that of the service pattern (marked "Proof"), and a couple of rounds with blank charges are fired to further set up the copper; after which the ring is finally bored up to its proper size, the block (finish boring, No. 6) now carrying 14 knives set to their proper position for finished boring (see Fig. IV, p. 351).

In using the boring blocks, Nos. 4, 5, and 6, should the copper ring not be bored entirely through, a washer should be cut out of a piece of paper tin, and placed *behind* the cutter-blocks, which will give them an increased forward motion.

FIG. IV.—(BORING.)

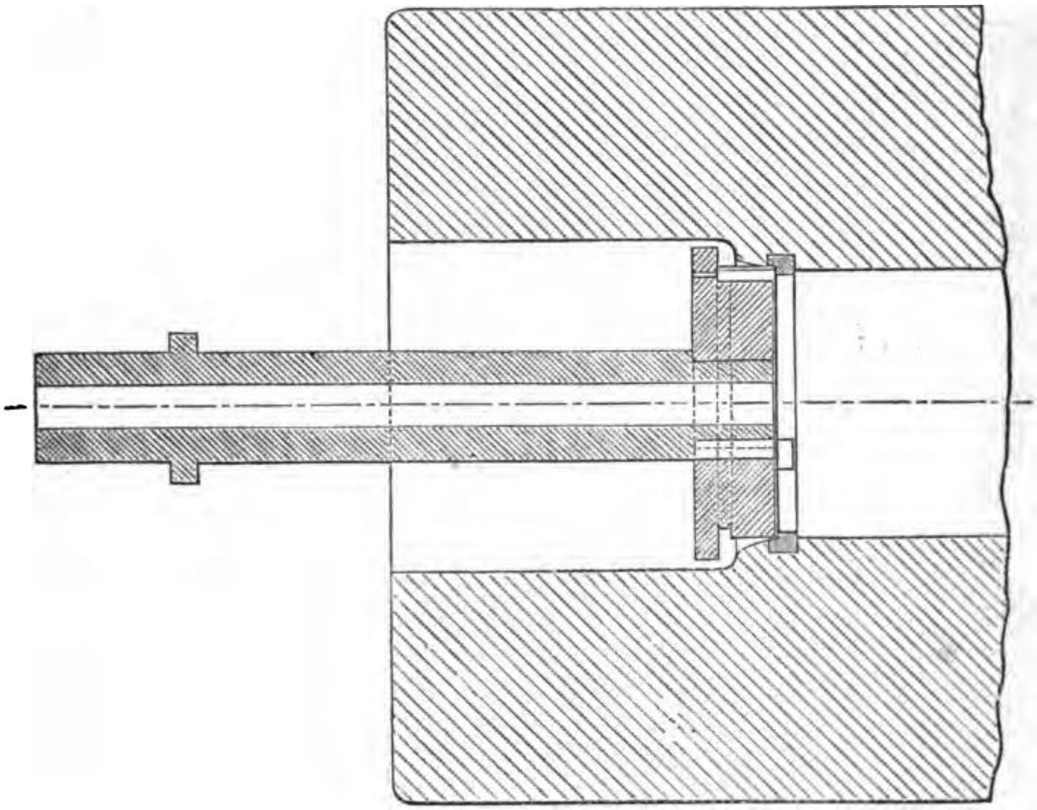
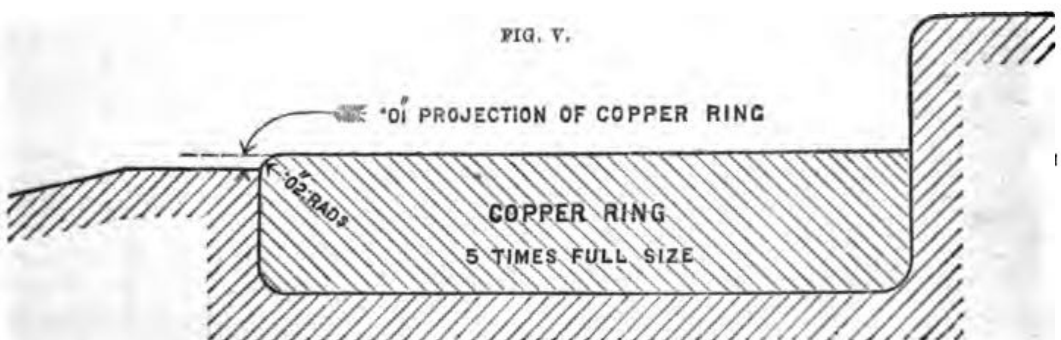


Fig. V is intended to show the copper ring (6-inch) after completion of the work; it exhibits the projection of the copper over the steel surface.

FIG. V.



*Facing Operations for R.B.L. Guns.**

Detailed instructions are contained in the boxes of implements issued for refacing and renewing both the copper ring on vent-piece and the copper breech-bush. In the operation of refacing, only just sufficient metal should be removed to render the angle face quite smooth and true.

Renewing the breech-bush.

For renewing the breech-bush a bearing, which is called the powder chamber guide-block, is put into the bore in front of the bush for the boring spindle to work in. (See *a*, Fig. 1, p. 352.) The face of the breech-bush which is to fit against the A-tube is coated with red-lead,

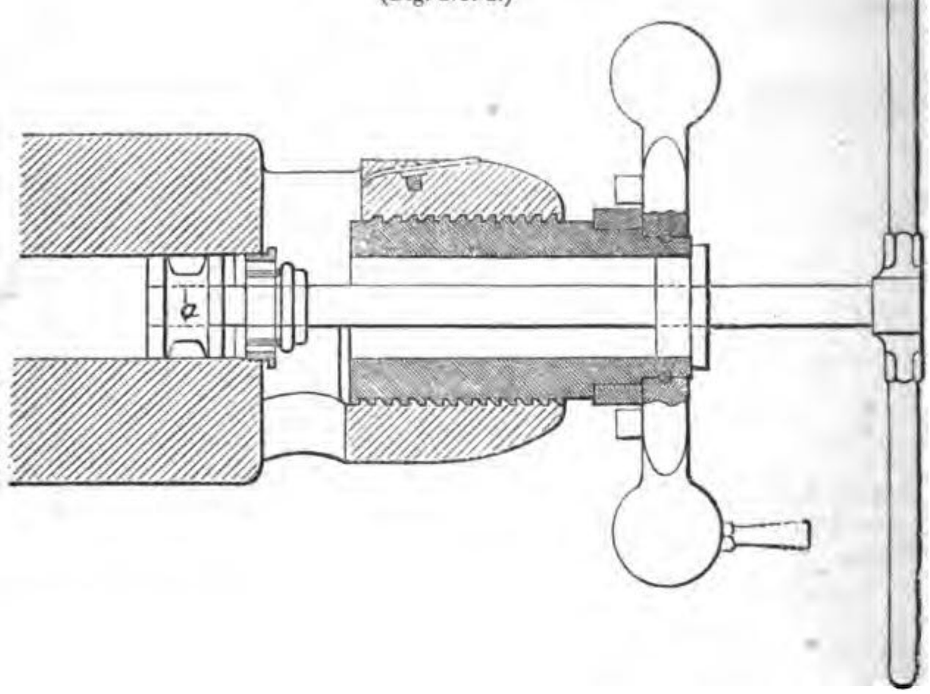
* For list of tools issued for each nature, see p. 365. *Vide* also Appendix, p. 382.

CHAP. II.

and the bush is screwed into the gun (Fig 1) as a trial, and on being unscrewed, if the red-lead shows that the bush does not fit evenly all round, it is scraped or filed down on the high parts. It is important that the face should fit perfectly tight to the barrel, for if the slightest space be left, the powder gas will eat into it. On being screwed in finally it is sent well home by striking the lever with a handspike. The ring is then upset with the upsetting block G (Fig. 2); it is next bored out, the spindle is introduced through the breech-screw, with two guide-blocks in the screw, one in front and one behind, and the knife is fixed through the spindle by inserting the hand in the slot; the spindle is turned by a wrench and fed to its work by means of the breech-screw.

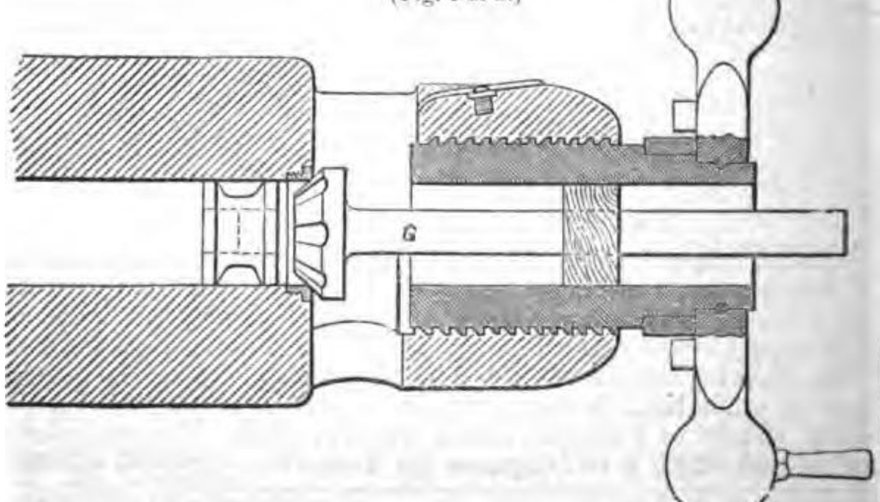
SCREWING IN BREECH-BUSH.

(Fig. No. 1.)



SETTING UP BREECH-BUSH.

(Fig. No. 2.)

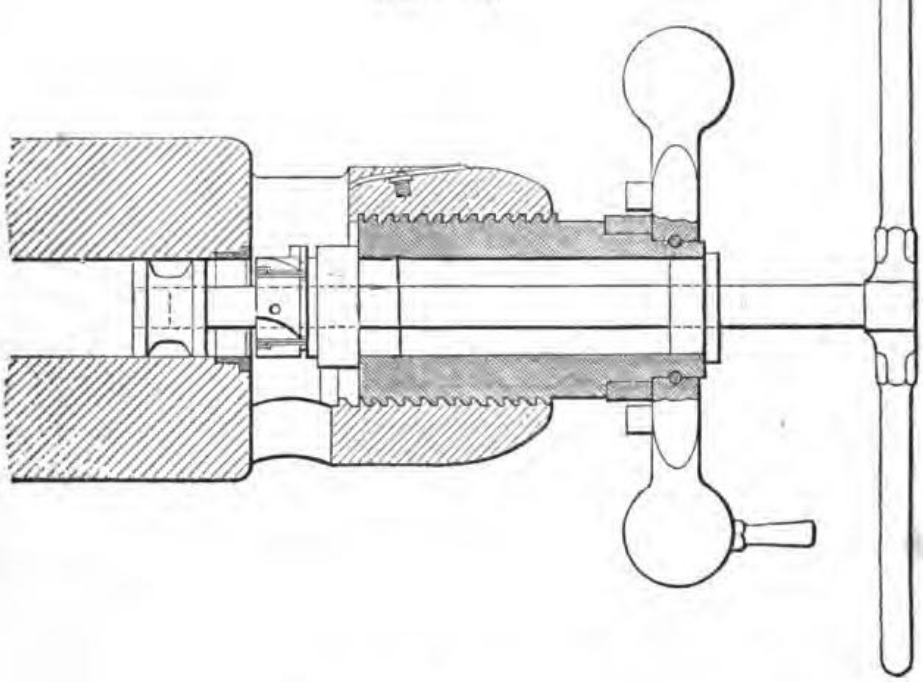


CHAP. II.

After boring, a different tool is fitted on to the spindle, and the copper is faced to within ·03 of an inch of the face of the A-tube, the cone part being left ·15 broad. (See Figs. 3 and 4.)

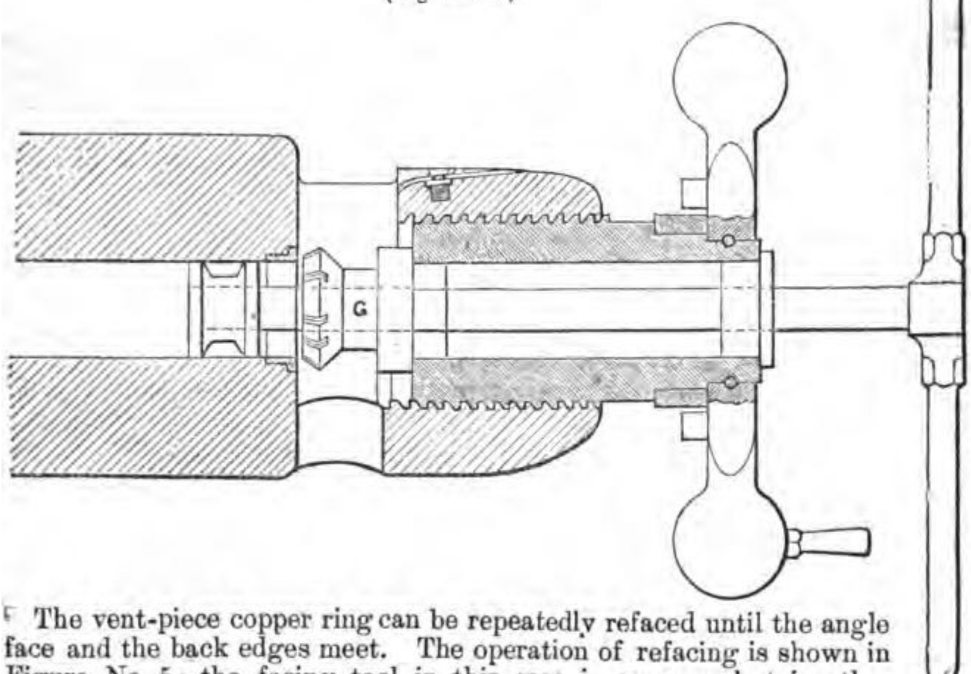
BORING AND FACING BREECH-BUSH.

(Fig. No. 3.)



ANGLE-FACING BREECH-BUSH.

(Fig. No. 4.)



Refacing vent-piece.

The vent-piece copper ring can be repeatedly refaced until the angle face and the back edges meet. The operation of refacing is shown in Figure No. 5; the facing tool in this case is concave, but in other respects similar to that used for refacing the breech-bush. When there is insufficient copper left in the ring, it can be removed by striking it a few smart blows with a hammer on the cone face, when the ring is so

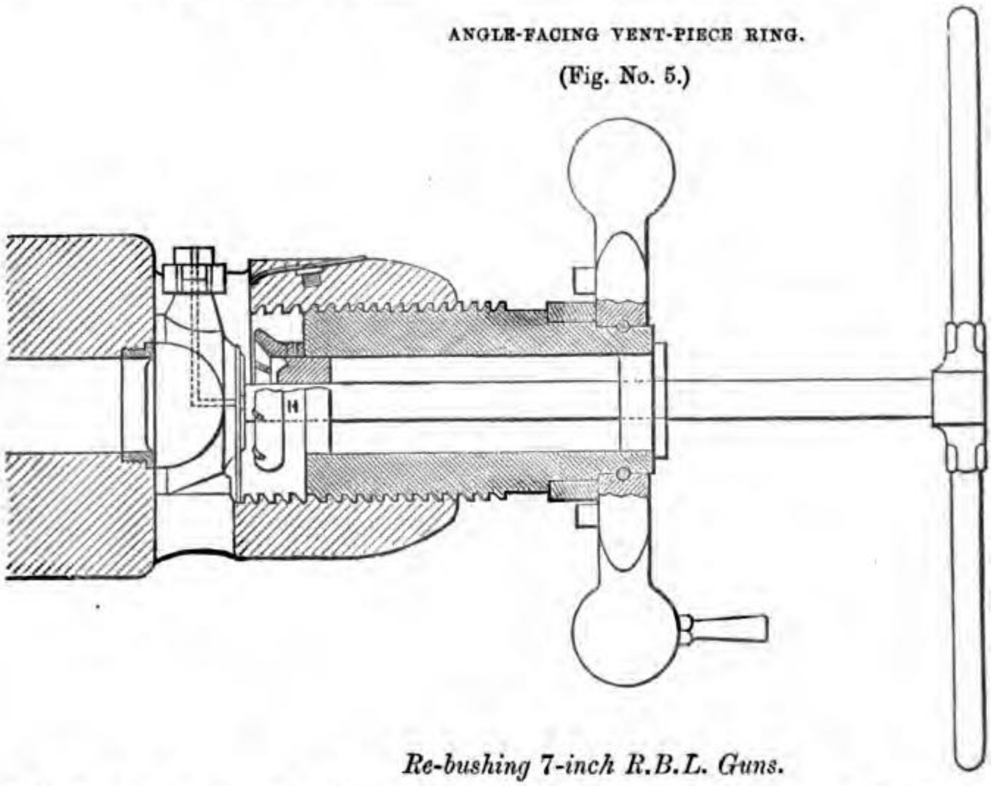
CHAP. II.

Fitting new copper ring.

much expanded that it flies off. The new one is put on by hand, and the vent-piece having been placed in the gun face to the rear, the ring is forced on by screwing up the breech-screw. It is necessary to place one of the guide blocks in the face of the breech-screw to prevent its injuring the copper.

ANGLE-FACING VENT-PIECE RING.

(Fig. No. 5.)



Re-bushing 7-inch R.B.L. Guns.

Re-bushing 7-inch guns.

The re-bushing of 7-inch R.B.L. guns is a more difficult operation than that of copper-bushing the smaller natures, requiring a gang of men: it would be performed only at large stations and arsenals at home or abroad, where the necessary tools are provided.

The set of implements is given at p. 365. The tools are similar but much stronger than those of the smaller sets.

Re-bushing a Vent-piece.

To re-bush a vent-piece.

In a workshop there is generally no difficulty in boring ont the old copper bush in a vent-piece with the drill supplied for this purpose, but in the field a bearing must be devised for the head of the drill, and this can be managed in the following manner:—

Lash one handspike firmly across the top of the wheels, and on the middle of this lash another so that the point projects over the trail. Tie a steadying cord to the handspike with each end made fast to the side of a wheel. The vent-piece must be tightly screwed up in the gun, and the ratchet of the drill should be se tat full height before commencing to work, with a small plate of iron between the drill-head and the handspike. The point of the handspike must also be tied down to the trail, and pressure on the top of the drill can be maintained by means of a Spanish lever. Care must be taken to drill right down to the bottom of the copper before removing the screwed piece at the top, otherwise some difficulty will be found in removing the lower pieces. The bush will be renewed from the spare ones issued for this purpose, and the upper surface will be finished in exactly the same manner as the copper bush in a muzzle-loading gun.

Repair of Sights.

(1) Method of adjusting a new muzzle-sight on an R.M.L. gun.

Muzzle-sight.

This operation may be performed on a 7 or 9-pr. gun, or on a 64-pr. converted gun of 58 cwt.

The damaged sight is first removed with a wrench supplied for this purpose, and a new sight with a square leaf or top is screwed tightly in, taking care that the direction of the leaf is parallel to that of the axis of the gun.

The gun must now be levelled in the bore, or its inclination obtained by a quadrant, and the rough sight is filed down until a straight-edge applied to the tops of the hind- and fore-sight is parallel to the axis of the piece, the hind-sight being carefully set at zero. This ensures correctness as to *elevation*.

The radius distance (obtained from a table) should then be measured from the back of the hind-sight, but in these small sights it may be considered sufficiently accurate to take the centre point of the leaf. The sight being next removed from the gun, the front and back slopes are filed down in a vice, taking care to leave a narrow part of the surface which has just been adjusted for height. For direction, the vertical lines on the muzzle are carried up by means of a straight-edge, and a silk line is stretched from this to the notch on the breech, and the side slopes filed so as to leave the highest point immediately under the silk line. Finally the back slope is roughened with a cold chisel.

64-p. cwt.

With the 64-pr. gun the hind-sight must be raised to its clearance angle instead of being placed at zero, and the height and direction of the sight on the muzzle must bring all three sights exactly in line. The position of the foresight will be found to lie on the right of the vertical line on the face of the muzzle when looking over the gun from the breech.

The new sight should be blued before it is finally screwed into the gun; and the accuracy of its adjustment should always be tested again after the work is completed.

(2) Method of adjusting a screw trunnion sight on an R.M.L. gun.

Screw trunnion sight.

Generally a new leaf can be fitted to the pillar of the old sight, but spare sights may be used if the pillar itself is damaged. The new sight in any case must be first screwed on to the gun with the rough leaf parallel to the axis of the piece.

There are two ways of carrying out a repair of this kind in the field:—

1st method.

(*a*) By laying the gun with its undamaged sights on some distant object, say not less than 2,000 yards off, for the distance must be sufficiently great to render the angle subtended by the breadth of the gun immaterial. Then file down the top of the leaf of the new sight until exactly in line with the object when looking over the sights on that side.

File the front and back slopes for the radius distance which may be found on the other side of the gun; then file also the sides very carefully until the apex covers the object on which the gun has been laid. Remove the sight to a vice to rough the back slope; blue the sight, screw it into the gun, and if correct mark a curved line with a scriber on the pillar of the sight just level with the surface of the gun, as a guide for replacing it if taken off for transport or drill.

2nd method.

(*b*) Second method:—In hazy weather, or when no distant point can be seen, another plan may be resorted to, which is more suitable for a workshop, and requires more time and care.

When the sight with rough leaf has been properly screwed into the

CHAP. II.

gun, its height can be adjusted by filing until a straight-edge placed on it and the hind-sight is seen to be parallel to the axis of the bore. Care must be taken that the hind-sight is set exactly at zero and this will give the height of the other for a full sight.

To obtain the adjustment for line it is necessary to stretch a silk thread through the notch of the hind-sight equidistant both at muzzle and breech from the vertical plane through the axis. To do this a disc of wood must be wedged in the bore with a small slip so pivoted on it that one edge planed perfectly straight can be made to coincide with the vertical line on the face of the piece. To this upright a cross-piece must then be attached with its upper edge (planed straight) set at right angles with a T-square to the vertical edge.

To find a point on the cross-bar equidistant with the notch on the hind-sight from the line of metal or vertical plane through the axis:—take another slip of wood and shape it so as to rest on the breech touching the tops of the hind-sights: on this mark the position of the line of metal and centre of the notch of the sight. Transfer the piece of wood to the muzzle, and apply the "line of metal mark" to the vertical edge of the cross-bar; the other mark will then give the lateral distance at which to attach the silk thread. Stretch a line thence to the hind-sight: this line will give the *direction* for completing the adjustment of the sight. File and finish as already described.

Method of adjusting a screw trunnion sight on a B.L. gun.

Screw trunnion sight on B.L. guns.

Sighting instruments are only issued to certain stations, so it may be found necessary to adjust a new sight without them: this may be done by making wooden copies of the proper instruments, and using them in the manner which will now be described.

The requisite materials are:—

Two blocks or discs of wood to fit into the breech and muzzle, with wedges to jam them firmly in the bore.

Two rectangular pieces of wood long enough to project beyond the tangent sights on either side, and of such width that the upper edge shall be level with the top of the tangent sight when the lower edge coincides with the line of horizontal axis marked on the breech of the gun.

Four screws and a few tacks, to fasten these pieces together and to the discs in the gun.

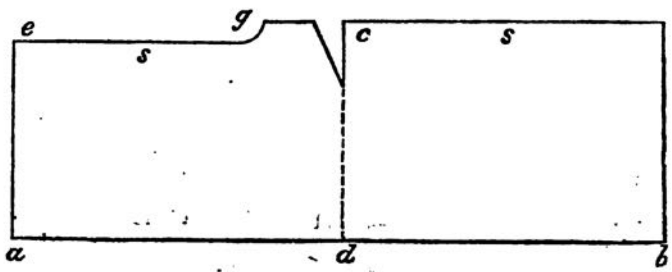
A silk or thread line.

The object of the operation is to obtain a line on either side of the gun through the tangent sight notch parallel to the axis of the bore.

Preparation of sighting plates in wood.

(1) Remove the breech-screw and fasten the breech and muzzle discs in the gun securely by wedges; a chip must be taken off of each disc for the wedge to be inserted to jam the disc in the bore.

(2) Fasten the two rectangular pieces together and plane their lower edges *a b* (as in figure) perfectly level, and square with the sides of the



boards, treating them as one piece of wood. Then square up a line *c d* near the centre at right angles to *a b*, and cut away the wood on one side in order that the straight-edge *c d* may be applied to the vertical line

on the breech of the gun. The upper portion of the line *c d* must be cut with great care so as to be true for either side of the board. CHAP. II.

(3) Now place *a b* against the horizontal line on the breech, and test with the point of a knife to make sure that *c d* coincides with the vertical line; then fasten the boards by two screws to the disc in the breech of the gun.

(4) Cut away the top of the boards until level with the notch of the tangent sight; the left side *e g* will require to be cut away more than the right. Formerly the level was taken from the bottom of the notch, but for a "full-sight" the straight-edge should be just laid on the top.

(5) Then with a rule or a T-square (if there is one) mark a line say at *s* on the top of the two boards opposite the centre of the notch of the wind sight on the side which requires repair.

(6) Remove the boards from the gun and separate them, fastening one at the breech and the other at the muzzle; taking care to adjust them to the horizontal and vertical lines on the gun.

(7) Stretch a silk line from the mark *s* on the breech board to the corresponding mark at the muzzle: this should pass through the centre of the notch of the tangent sight; if not the line must be shifted, but care must be taken to move the line the *same amount at both ends* so as to keep it parallel to its original position. This line will be parallel to the axis of the gun.

Adjusting new sight.

(8) A new trunnion sight (or the old pillar with a new leaf) being placed in the gun and adjusted with the leaf parallel to the silk line, the top is filed down very carefully to the level of the thread. In doing this it is usual to raise the line at one end by placing a piece of paper, folded two or three times, between it and the board: when one thickness of paper only remains, the line should just clear the leaf, and when this is removed it should touch.

(9) The position of the apex of the new sight is obtained by the length of the radius distance for the particular nature of gun. The apex is not in the centre of the leaf except in 6 and 9-pr. screw guns. It is usually found in a practical manner by cutting a template out of sheet tin to fit the pillar and slopes of an undamaged sight: the intersection of the two slopes should be a trifle higher than the top of the sight, leaving a small portion of the surface intact by the file when adjusting the height.

(10) Remove the sight from the gun, and file down the back and front slopes in a vice. The length of slope is not really important if the apex has been rightly determined; but it must be sufficiently long for the sight to present only a point to the view when laying the gun at its highest elevation.

(11) Replace the sight in the gun and file the lateral slopes, so that an edge is obtained under the silk line, taking care that the top of the leaf is not made too sharp, as that would render it liable to injury. In the case of a screw sight, a curved line is then marked by a scriber on the outer side of the pillar to show the level of the surface of the gun, and the position of the sight when screwed home.

(12) Once more the sight is removed for the back slope to be roughed, and then it should be blued before it is finally fixed on the gun.

Adjustment of a new leaf in a drop-sight, M.L. or B.L. gun.

New leaf in a drop sight.

This operation may be required for either M.L. or B.L. guns. It is very much simpler than those already described, as drop sights are interchangeable. The damaged leaf must be removed and a new one affixed to the gun-metal pillar by a small screw, the old screw will most likely answer for this purpose again. The height can then be determined by means of a silk thread stretched from the notch of the

CHAP. II. tangent sight to a piece of wood pivoted on a disc in the muzzle, its position being regulated by the top of an undamaged sight temporarily placed in the socket. This thread will also supply the direction for the slopes of the leaf, if care is taken that the silk thread not only just touches the good sight, but also passes over the centre of it. The radius distance or position of the point is marked on the leaf, and the slopes are then filed as described in the case of a screw-sight. The leaf should be removed afterwards for roughing and blueing; and the tests for adjustment should be once more applied when the work has been altogether completed.

To replace a broken clamping screw.

Broken clamping screw.

The mill-headed screw which is sometimes employed to clamp the tangent sight in R.M.L. guns may possibly be broken off near the head; it can, however, be replaced in the following manner:—

Remove the small screw marked A in the figure on the next page for a 9-pr. R.M.L. gun, which secures the steel patch marked B; then drive out the latter in the direction of the cascable by means of a mallet and copper set. Now apply a hard piece of wood to the bottom of the socket, through the hole bored in the gun for the reception of the sight, as shown by the arrow, and drive up the gun-metal socket out of the gun.

Take out the broken screw through the hole in the front or muzzle side of the socket (it cannot be withdrawn any other way) and replace it by a new one, taking care that the swivel-nut is in proper position; the curved face of the nut should be lengthways in contact with the tangent bar when placed in the socket. Put the socket back in the gun, and make it secure by reversing the operations of extraction.

Adjusting Millar's sights of a S.B. gun.

Millar's sight on S.B. gun.

The gun having been carefully levelled laterally across the trunnions, and longitudinally in the bore, the fore- and hind-sights must be adjusted so as to fulfil the following conditions:—

1st. They are to be the exact distance apart, according to the short radius given in Table XVI, p. 108.

2nd. When the scale is at zero the line joining the top of hind- and the top of fore-sight must be parallel to the axis.

3rd. When the scale is raised to the full elevation marked on it—that is, to the "clearance angle"—the top of the scale, the apex of the fore-sight, and the highest point on the muzzle of the gun must be in line.

4th. The line of sight must be made to coincide exactly with the same vertical plane as the line of metal.

A dummy fore-sight is laid on the gun over the second reinforce. The hind-sight is then adjusted by hand until the conditions are fulfilled.

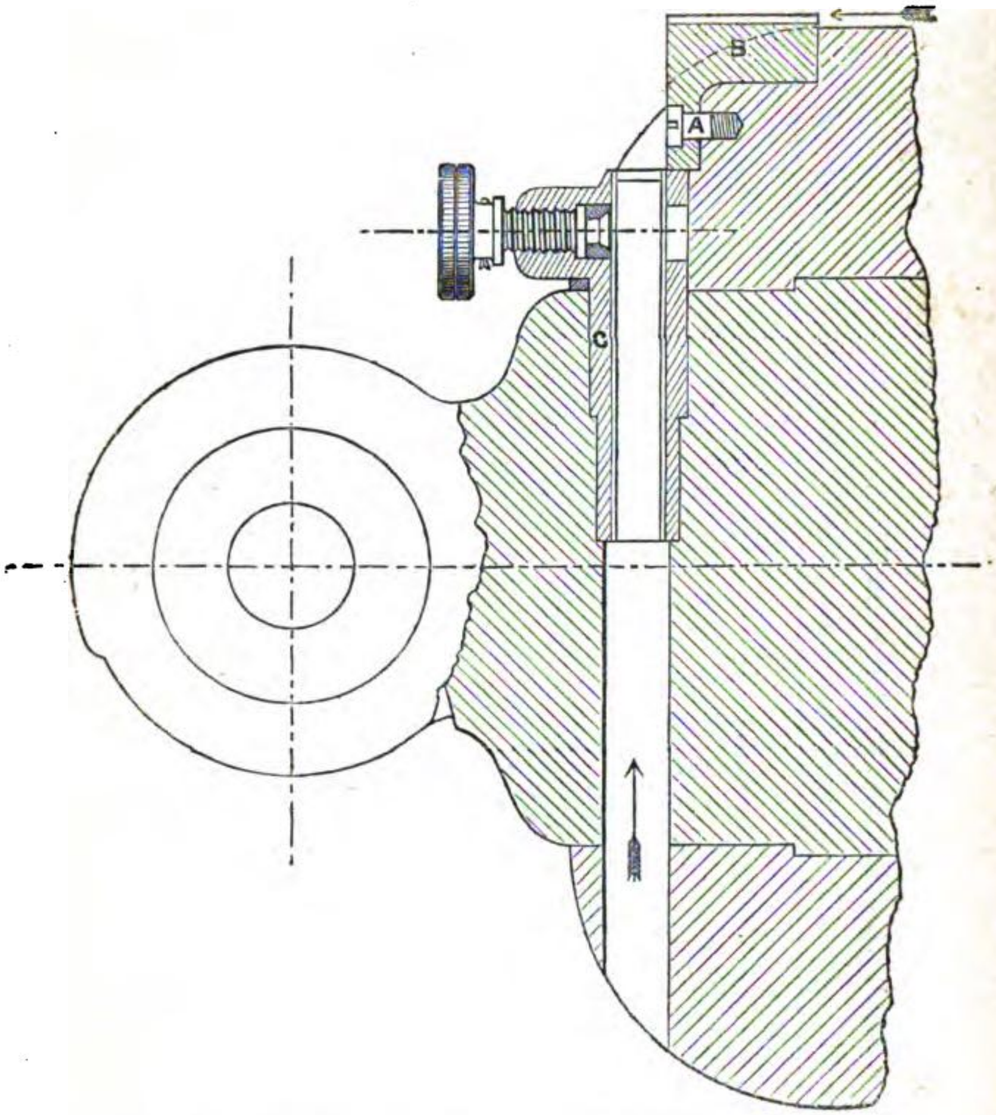
The angular level is used to bring the hind-sight to the angle of 76°. The positions for the hind-sight screw holes are then marked with a scriber on the gun through the holes previously drilled and punched through the sight block and lead packing.

The holes are drilled with the instrument called "machine drilling hind-sight," and care must be taken to drill the holes perpendicular to the face of the sight-patch, so that the heads of the screws may rest fairly on it; the holes are then tapped.

The hind-sight being fixed, the scale is raised to a little more than the clearance angle, and a silk cord stretched from the notch on it to that on the muzzle. The real fore-sight is now adjusted so as to bring its top under the silk cord at the proper distance from the tangent sight.

The position of the fore-sight screw holes being marked, they are

9-PR. WROUGHT-IRON R.M.L. GUN OF 6 OR 8 CWT.



drilled and tapped, and the sight screwed on. The head of the sight is then filed down to the proper height, and the position of the ridge being marked, it is unscrewed, and the side slopes filed down. When again screwed on, the sighting is tested to ascertain whether the whole of the conditions are fulfilled.

The sights and lead packing are then marked with the number of the gun to which they have been fitted, and the screws are also marked for their particular holes.

When guns are mounted, the sights are removed from the piece to be kept in store, and the screw holes are filled with preserving screws, but these are to be taken out when the guns are shifted, as the screw heads are liable to be broken off; the holes are then filled with tallow and white lead composition, or simply with tow and grease.

Some tables are given on the following pages of the tools and materials required for the various operations which have just been described.

TABLE XL.—VENTING AND REPAIRING TOOLS.

Distribution List of Tools for Venting and Repairing Ordnance, showing what are required for each nature.

Nature of Article.	S.B.*								R.M.L., R.B.L., and B.L.																			Remarks.
	8-inch Guns, and Mortars.	10-inch Mortars.	68-pr.	32-pr.	24-pr.	18-pr.	12-pr.	13-inch Mortar.	12·5-inch.	12-inch.	11-inch.	10-inch.	9-inch.	8-inch.	7-inch.	80-pr.	64-pr., 58 & 71 cwt.	8-inch, 70 & 46 cwt. Howitzer.	6·6-inch Howitzer.	6·3-inch Howitzer.	·6 nch.	64-pr., 64 cwt.	40-pr. & B.B.L. side closing.	25-pr.	16-pr. & 13-pr.	9-pr.	7-pr.	
Venting.																												
Blocks, adjusting, for instrument No. 1 for taking impressions of vents	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	a	a	...	...	...	...	2	...	...	...	...	...	
Blocks, adjusting, for No. 2 do. do. do. ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2‡	1	1	1	...	1†	1	1‡	...	...	† Not for R.B.L.
Blocks, expanding (pairs)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	
Blocks, stop (for vents)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	
Blocks, pulley, 4-inch, treble and double, with fall	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...	
Braces, smith's	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a'	a	
Braces, ratchet, 12-inch	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a	a	a	a	a	
Braces, ratchet, 20 "	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	...	...	...	...	a	...	...	...	...	...	
Brushes, gun, soft, small (with stave in 2 lengths)...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	
Chests, for tools, venting, siege train ordnance (A)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Chests, for vents for ditto ... ... (B)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Chisels, cold, flat, 8-inch by 1-inch (set of five); gravers (set of three)	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	
Cutters, rose	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...	
Cylinders, guide	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...	
Drifts, vent, square (for taking out old vents), ¼-inch	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	
Drifts, vent, square, 6 "; 8½ "; 10½ "	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a	a	a	a	...	
Drifts, vent, square, F; F1; F2; F3; F4	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	a	...	...	...	...	...	
Drifts, vent, square, F5	...	...	...	...	...	...	...	...	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...	...	...	...	...	

Drill post, 29 inches high, complete with wrench, tommy, clamp, 2 foot plates, and 2 lengths of chain (15 feet each length) ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Drills, cone vent, ¼ inch ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Drills, cone vent, 1¼ " ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a	a	a	a	...
Drills, cone vent, G, G1 ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	...	...	a	...	...	...	...	...
Drills, drifting vent, ¼-inch ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Drills, drifting vent, 4 ", 10 " ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a	a	a	a	...
Drills, drifting vent, E, E1, E2, E3, E4 ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	a	...	...	...	...	...
Drills, tapping vent, ¼-inch ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Drills, tapping vent, 4 ", 10 " ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a	a	a	a	...
Drills, tapping vent, B, B1, B2, B3, B4 ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	a	...	...	...	...	...
Drills, vent, hollow, ¼-inch ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Drills, vent, hollow, 1¼ " ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a	a	a	a	...
Drills, vent, hollow, A, A1 ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	a	...	...	...	...	...
Files, bastard, safe edge, with handle, 14-inch ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Files, smooth, safe edge, 10-inch ...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	...	...	a	a	a	a	a	a	a	a	a	a
Frames, trunnion, with cross-head complete (4 pieces)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...
Gauges, vent, short ...	a	a	a	a	a	a	a	a	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a
Gauges, vent, long ...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...	...	...
Gouges, cold, 9 inch by 1 inch ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Gyns, triangle, 10 feet ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...
Hammers, fitters' 24-oz. ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Hammers, fitters' 8-oz. ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Instrument for taking impressions of vents, No. 1 ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	a	...	...	...	...	...
Instrument for taking impressions of vents, No. 2 (with plate) ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a†	a	a	a	a
Monkey ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...
Pieces, lengthening, for No. 1 instrument (for taking impressions of vents, for 9-inch to 12·5-inch R.M.L. guns) ...	...	...	...	...	...	...	...	...	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Plates (for taking impressions of vents) for No. 1 instrument, A ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...	...	...
Plates (for taking impressions of vents) for No. 1 instrument, B ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	...	...
Plates (for taking impressions of vents) for No. 1 instrument, C ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...

† Not for R.B.L.

* (A) To contain all the tools for Siege Train Ordnance. ‡ One for each nature. a. Common to all these.

(B) To contain copper bushes, viz. { 3-inch, 12. 7½ ", 18. 10½ ", 30. }

* The tools for 32-pr. S.B. B.L. Same as for 40-pr. side-closing.

DISTRIBUTION LIST OF TOOLS FOR VENTING AND REPAIRING ORDNANCE—*continued.*

Nature of Articles.	S.B.								R.M.L., R.B.L., and B.L.																			Remarks.
	8-inch Guns, and Mortars.	10-inch Mortars.	68-pr.	32-pr.	24-pr.	18-pr.	12-pr.	13-inch Mortar.	12·5-inch.	12-inch.	11-inch.	10-inch.	9-inch.	8-inch.	7-inch.	80-pr.	64-pr., 58 & 71 cwt.	8-inch, 70 & 4 cw., Howitzer.	6·6-inch Howitzer.	6·3-inch Howitzer.	6·6-inch.	64-pr. 64 cwt.	40-pr. & R.B.L. side closing.	25-pr.	16-pr. & 13-pr.	9-pr.	7-pr.	
Venting—continued.																												
Rimers, cone, ¾-inch	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	
Rimers, cone, 1¼ ,,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a	a	a	a	...	
Rimers, vent, H, H 1	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	...	...	a	...	...	...	...	...	
Rimers, mouth of vent	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	a	...	...	...	...	a	...	...	...	a†	a†	† Naval.
Rimers, vent, short ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	
Rimers, vent, long* ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...	* 26 in. long.
Rod, with hook ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...	
Saws, with frame, 14-inch	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	
Socket (for ratchet brace)	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...	
Spanner, for cutter rose	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...	
Taps, vent, bush, ¾-inch, Nos. 1, 2, and 3 ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	18 threads.
Taps, vent, bush, 1¼ ,, Nos. 1, 2, and 3 ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a	a	a	a	...	7 threads.
Taps, vent, bush, short C1, C2, C3, C4, C5	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	a	...	...	...	...	...	
Taps, vent, bush, long C3, C4, C5	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...	...	...	
Taps, vent, bush, D3, D4, D5	a	a	a	a	a	a	a	a	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...	6 threads.
Wedges (expanding blocks)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...	
Wires, directing, 48-inch	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...	
Wires, directing, 18 ,,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	
Wrenches, for cutter rose ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	...	...	...	...	...	...	...	...	...	...	
Wrenches, for tap, vent, bush	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	a	...	...	...	...	...	
Wrenches, for taps and vents, large	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	a	a	a	...	a	a	a	a	...	
Wrenches, for taps and vents, small	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	
Wrenches, for vent, bush ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...	

REPAIRING.

Braces, ratchet, 9 inch	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Drifts, square, sets of 5 (¼, ⅜, ½, ⅝, ¾)...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Drill post, for ratchet brace, 20 inches high, with chain	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a		a	a	a	a	a	a
Drills, brace, ratchet, sets of 11 (⅛-inch to ¾-inch)...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Files, Fish-backed, bastard, 12-inch	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	o	a	a	a	a	a	a	a	a	a	a	a
Files, Fish-backed, smooth, 12 ,, ...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Files, Fish-backed, bastard, 14 ,, ...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Files, Fish-backed, smooth, 14 ,, ...	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Files, bastard, round, taper, sets (12- and 16-inch)	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Machines, rifling, hand (complete)	...	...	...	...	...	...	...	...	1	...	1	1	1	...	1	a	a	1	1	...	...	...	...	...	...	...	...
Rimers, drop sight socket	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	...	...	...	...	...	...	...	...	...	...
Sets, socket, drop sight	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	...	...	...	...	...	...	...	...	a	...
Tap and dies, Whitworth, set complete, ¼-inch to 1¼-inch	...	...	...	...	...	...	...	...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	
Wrench, sight, R.M.L. muzzle, hog-back	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	...	...	...	...	...	...	...	...	†	...

a Common to all these.
† For L.S. guns only.

CHAP. II.

TABLE XLI.

TOOLS, RE-COPPERING, B.L. ORDNANCE.

Description of Store.	6-inch (80 pr.) 80 cwt. (Mark I) Set.	6-inch 81 cwt. Mark II. (Mark I) Set.	4-inch 22 cwt. Mark I. (Mark I) Set.	Remarks.
Blocks.. Guide, with pinion-handle and tommy	1	1	1	
Blocks.. No. 1, with 2 cutters ..	1	1	1	
Blocks.. No. 2, in 3 parts	1	1	1	
Blocks.. No. 3	1	1	1	
Blocks.. No. 4	1	1	1	
Blocks.. No. 5	1	1	1	
Blocks.. No. 6	1	1	1	
Cup, obturating (expanding copper ring)	1	1	1	
Drift, for block No. 2	1	1	1	a Common to all natures.
Spindle, with lever, block No. 3 ..	*a*	*a*	*a*	
Wrenches (for feed nut)	1	1	1	

NOTE.—The stores for each nature of B.L. guns are of the same pattern, differing only in size, except those marked (*a*) which are common to all.

TABLE XLII.

CHAP. II

LIST of FACING IMPLEMENTS for R.B.L. GUNS.

6-PRS.

In a box, with hinges and hasps, and padlock with two keys.

	Letter.	No. of each.
Blocks, breech bush copper, angle facing	L	1
Blocks, breech bush copper, finish boring	K	1
Blocks, breech bush copper, screwing in	H	1
Blocks, breech bush copper, upsetting	I	1
Blocks, vent-piece ring, angle facing ...	N	1
Cutters, breech bush copper, cutting out	G	1
Cutters, breech bush copper, facing...	M&M1	2
Cutters, breech bush copper, rough boring	J	1
Guard, wood, for vent-piece	Q	1
Guides, in breech screw	D	2
Guides, in powder chamber	E	1
Guides, wood (block upsetting), two parts...	O	1
Key, for fixing cutters	F	1
Lever	B	1
Punch, for pin in spindle	R	1
Spindle	A	1
Washers, stop	C	2
Wrench, for stop washers	P	1

12 & 9-PRS.

In a box, with hinges and hasps, and padlock with two keys.

	Letter.	No. of each.
Blocks, breech bush copper, angle facing	I	1
Blocks, breech bush copper, finish boring, 3·125 diameter	F1	1
Blocks, breech bush copper, finish boring, 3·2 diameter ...	F2	1
Blocks, breech bush copper, screwing in	D	1
Blocks, breech bush copper, upsetting	C	1
Blocks, vent-piece ring, angle facing ...	J	1
Cutters, breech bush copper, cutting out	K	1
Cutters, breech bush copper, facing	G & G1	2
Cutters, breech bush copper, rough boring	E	1
Guard, wood, for vent piece	S	1
Guides, in breech screw	M	2
Guides, in powder chamber, 3·125 diameter ...	N1	1
Guides, in powder chamber, 3·2 diameter	N2	1
Guides, wood (block upsetting), two parts	R	1
Key, for fixing cutters	O	1
Lever	B	1
Punch, for pin in spindle	P	1
Spindle	A	1
Washers, stop	L	2
Wrenches, for stop washers	Q	1

20-PRS.

In a box, with hinges and hasps, and padlock with two keys.

	Letter.	No. of each.
Blocks, breech bush copper, angle facing	K	1
Blocks, breech bush copper, finish boring, 3·875 diameter ...	I 1	1
Blocks, breech bush copper, finish boring, 3·94 diameter ...	I 2	1
Blocks, breech bush copper, screwing in	G	1
Blocks, breech bush copper, upsetting	M	1
Blocks, vent-piece ring, angle facing ...	L	1
Cutters, breech bush copper, cutting out	F	1
Cutters, breech bush copper, facing...	J & J1	2
Cutters, breech bush copper, rough boring	H	1
Guard, wood, for vent-piece	P	1
Guides, in breech-screw	C	2
Guides, in powder chamber, 3·875 diameter ...	D1	1
Guides, in powder chamber, 3·94 diameter ...	D2	1
Guides, wood (block upsetting), two parts	Q	1
Key, for fixing cutters	N	1
Lever	B	1
Punch, for pin in spindle	R	1
Spindle	A	1
Washers, stop	E	2
Wrenches, for stop washers	O	2

40-PRS. (*See* NOTE.)

In a box, with hinges and hasps, and padlock with two keys.

	Letter.	No. of each.
Blocks, breech bush copper, angle facing	G	1
Blocks, breech bush copper, finish boring, 4·91 diameter ...	F1	1
Blocks, breech bush copper, finish boring, 4·96 diameter ...	F2	1
Blocks, breech bush copper, screwing in	E	1
Blocks, breech bush copper, upsetting	M	1
Blocks, vent-piece ring, angle facing ...	H	1
Collar, for feed motion...	BO	2
Cutters (in block)	D	1
Guides, in breech-screw	A1 A2	1 1*
Guides, expanding, in powder chamber ...	C	1*
Guides, wood (block upsetting), two parts	N	1
Handle to hold blocks in vent chamber ...	P	1
Lever	J	1
Punch, for cutters in blocks...	K	1
Punch, for pin in spindle	L	1
Spindle	I	1*
Washers, stop	Q	1
Wrench, for stop washers	B	1*

7-INCH.

In a box, with tray, hinges and hasps, and padlock with two keys.

	Letter	No. of each.
Blocks, breech bush iron, cutting out, boring, facing, tapering, and angle facing.	G	1
Blocks, breech bush iron, screwing in, and rough boring.	F1	1
Blocks, vent-piece, angle facing	K	1
Cutters	HH	—
Cutters (cutting out, breech bush), thick iron	E2	2
Cutters (cutting out, breech bush), thin iron	E1	2
Guard, wood (for vent-piece)	O	1

	Letter.	No. of each.
Guides, in breech-screw	C	2
Guides, expanding in powder chamber ...	D1	1
Handle to hold blocks in vent chamber ...	P	1
Lever	B	1
Punch, for pin in spindle	N	1
Spindle	A	1
Washers, stop	J	2
Wrenches, for stop washers	M	1

NOTE.—This set of 40-pr. Facing Implements is the new pattern; the old pattern, which is not to be considered obsolete, consists of the same articles, with the omission of those marked *, and the insertion instead of the "Guide expanding," Guides in powder chamber {4·91 diameter—C 1—1. / 4·96 diameter—C —1.} See "Changes in Patterns," § 1073, No. 5.

CHAP. II.

TABLE XLIII.

SIGHTING TOOLS for SMOOTH-BORE ORDNANCE.

Articles.			No. to a set.	Remarks.
Battens, sighting, wood	inside	large	1	
		small	1	
	outside	large	1	
		small	1	
Braces	smith's		1	
	drilling, hand	medium	1	
		small	1	
Cases, wood, spirit level			1	
Chisels, cold	flat, 8 inches by 1 inch		2	
	graver's		6	
Drills (set of 3, ½-inch diameter)			3	3 lengths.
Hammers, fitter's, 8-oz.			1	
Levels	spirit	angular	1	
		adjustable	1	
	plumb for battens		1	
	bridge (with lead plummet)	large	1	
		small	1	
Machine, drilling (with chains complete)		fore-sight	1	
		hind-sight	1	
Plummets, sighting	brass		2	
	lead (for levels, bridge)		1	
Punches (steel)	centre		1	
	round $\frac{3}{16}$ inch by 7 inches		1	
Scribers			6	
Sets, V			1	
T-square (steel)			1	
Taps, sight, screw	carronade		3	3 sizes.
	gun		3	Do.
Wrenches, tap, sight, screw			1	

INSTRUCTIONS FOR RE-FILLING GRADUATIONS IN METAL GRADUATED ARCS AND ELEVATING ARCS.

1. When the colouring matter in the graduations on metal graduated arcs, and elevating arcs, becomes removed by wear, &c., the graduations will be re-filled locally, according to the following instructions. The operation in the case of arcs in charge of the Royal Artillery will be carried out by regimental artificers.

(*a*) *Arcs, metal, graduated.*

Take up the segments required to be re-filled.

Clean the surface with pumice stone and water, and carefully dry it.

Fill the marks with engravers' *black wax*, and the figures with engravers' *red wax*, both in a powdered state. Wax.

Heat the arc until the wax is melted, taking care it does not boil, and allow it to cool gradually.

When cold, rub off any superfluous wax with pumice stone and water and replace the segments.

(*b*) *Arcs, elevating.*

Remove the arc from the gun.

Clean the graduated surface with turpentine to remove any grease or oil.

Coat the surface with ordinary *black paint*. Paint and composition.

When dry, coat the surface with the *composition* supplied (which consists of patent knotting that has been thickened to the consistency of thick paste, by means of dry lamp black, carefully worked into the knotting).

Clean off the surface with pumice stone and raw linseed oil.

The pumice stone used should be large, and have a flat surface.

2. Stores in the following proportions will be required for this service, and will be issued on demand, viz.:—

For 5 segments of arcs, metal, graduated.

Wax, engravers'	red	$\frac{1}{2}$ lb.
	black	$\frac{1}{2}$,,
Stone, pumice		2 ,,

For 5 arcs, elevating.

Paint, black	$\frac{1}{8}$,,
Composition	$\frac{1}{8}$,,
Stone, pumice	1 ,,
Oil, linseed	$\frac{3}{4}$ pints

PART IV.

CHAPTER III.

ANNUAL AND SPECIAL RETURNS.

Annual returns.—Direction for completion.—Blank forms for S. B. ordnance not required.—Special returns.—Return of ordnance that have fired the prescribed number of rounds.—Army Form G 869 for S.B. ordnance.—Army form G 872 for R.M.L. ordnance.—Army Form G 925 for B.L. guns.—W.O. Form 1473.—Memorandum of Examination.

ANNUAL Returns on Army Forms G 869 for S.B., G 872 for R.M.L., and G 925 for B.L. ordnance will be sent yearly by Officers of Artillery in command of districts (except in North America) to the Director of Artillery and Stores on the 1st June. Those from North American stations will be furnished on the 1st November.

Officers commanding vessels of war of every description having guns on board, and likewise Royal Marines, Royal Naval Reserve, and Coast Guard having ordnance in their charge, will furnish similar returns on 1st January, through the Admiralty, to the Secretary of State for War.

These annual returns are forwarded to the Superintendent Royal Gun Factory for record and report if necessary. The forms are appended to the end of this chapter.

It is necessary for the identification of guns that the register number and descriptive marks should always be very accurately entered in the return.

The register number will be found on the left trunnion in all R.M.L. ordnance (except in the 7-pr. guns, when it will be found on right) and in all R.B.L. guns; but on the right trunnion of all other natures of B.L. guns except the 32-pr. S.B.B.L. guns, in which case it has been placed on the left.* In smooth-bore cast-iron ordnance the register number will generally be found on the reinforce.

The numeral of pattern or mark is engraved on the left trunnion in nearly all natures of ordnance, but with the B.L. guns of new type, the calibre, number, and mark are all placed together on the right. In some cases a letter will be found instead of, or in addition to, the numeral of mark. Letters on S.B. ordnance indicate the foundry where the guns were cast; these were usually placed on the right trunnion.

Under the head of "Nature," the proper designation of the gun should be briefly entered; for instance, "10-inch gun"—"8-inch howitzer"—"7-inch R.B.L. gun"—"40-pr. R.B.L. side closing"—"12-pr. S.B.," "12-pr. bronze." The correct designation can always be found in the "Vocabulary of Stores."

* Trunnionless guns are marked on face of the breech.

The weight given for all rifled ordnance should be the "nominal weight," but in the case of smooth-bore pieces this will be quoted if necessary in specifying the nature, the actual weight being stated in the next column, which is prepared for this purpose. The weight is always stamped on the top of the breech in front of the vent.

The "Date of last examination" will be the date of the last regular inspection conducted by an Inspector of Warlike Stores or other qualified person: this can be found on the Memorandum of Examination belonging to the gun, from which also the number of rounds fired since that date will be ascertained.

Condition of bore and sentence.

The "Condition of bore" and "Sentence" will be taken from the last report made by the Inspector of Warlike Stores, or other examiner conducting the periodical or special examinations; but if the gun has not been examined, owing to only a few rounds having been fired from it, these columns may be left blank, unless the Commanding Officer should see cause to call special attention to the gun.

Number of rounds fired.

The total "Number of rounds fired" up to the date of making the return will be very carefully entered under the several headings; it is exceedingly important, for the sake of the record, that the number should be given correctly.

All the older cast-iron guns which were in the service previous to records being kept have had a number of rounds "assumed" from the size of the vent. The number of "assumed rounds" will be entered every year in red ink, and the actual number of rounds in black ink.

Condition of fittings, B.L.

The columns regarding the condition of the fittings of the breech-loading guns and the vents of muzzle-loading guns will be filled in from the reports of the Inspector of Warlike Stores, or other examiner, unless anything has occurred to change their condition since the date of the last regular inspection.

Column "Remarks."

Particulars of any special defect on the exterior or other part of the gun will be noted in the column of "Remarks," if not entered in any other part of the return; also any peculiar circumstance, such as reventing, the bursting of a shell in the bore, the fracture of fittings, &c.; and reference will be made, when necessary, to explanatory documents and gutta-percha impressions.

All guns, whether fired or not, will be entered in the annual return; but the columns entered "Condition," "Sentence," "Rounds fired," and "Condition of fittings," need not be filled in; a remark that they have not been used since such a date being entered against them.

A blank return for S.B. ordnance is not required from districts in which there are no S.B. pieces on charge.

Special Returns.

When any accident occurs, at home or abroad, such as the bursting of a shell in the bore, splitting of a vent-piece, &c., inquiry should be at once made into the circumstance, and the gun should be thoroughly examined. If the Commanding Officer should consider the damage to be of importance, he will send without delay a report and special return through the same channel as that by which the annual return is rendered; forwarding, if necessary for illustration of his report, gutta-percha impressions of the damage. The special return will be given on the same form as the annual return, the word "Special" being substituted for "Annual." Firing from this piece will of course be suspended until a decision has been received.

CHAP. III.

Return after firing a series of Rounds.

Whenever a gun on charge of the Royal Artillery in the United Kingdom has fired the prescribed number of rounds since previous examination, a return on W.O. Form 1743 will be sent by the Commanding Officer of Artillery in the District to the Director of Artillery and Stores (except in the case of S.B. ordnance, when it will be forwarded direct to the Superintendent Royal Gun Factory). A copy of this W.O. Form is given at the end of the chapter. In all other cases, at home or abroad, the form for Annual Returns will be used; and directions have been given in a previous chapter to guide Commanding Officers on land or at sea for obtaining the services of a qualified artificer.

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(*First Page.*)

MEMORANDUM OF EXAMINATION.

ROYAL GUN FACTORY, WOOLWICH.

_______________, 188

B.L. Gun, 6-*inch*, 5 *Tons*.

Mark IV. No.__________ (__________ Issue).

The position of flaws, &c., is measured in inches from the muzzle. Their position round the Gun is noted according to the diagram.

[*The condition of the bore and any visible defects, &c., will be noted here: also subsequent repairs.*

Signed by the Superintendent Royal Gun Factory.]

CHAP. III.

(Second and Third Pages.)

RESULTS OF EXAMINATION AFTER EACH SERIES OF ROUNDS OR OTHER EXAMINATION.

Date.	No. of rounds with projectiles.*		Present condition of												Sentence on gun and fittings.	Remarks.§
			Gun.			Breech fittings.										
						Breech-screw.‡				Vent axial.		Obturation.				
	Since last examination.	Total to to date.	Powder chamber.	Bore.†	Threads in breech.	Threads.	Face.	Lever and small fittings on do.	Carrier.‡	Through	Front.	Pad.	Discs.			

* For purposes of calculation, four rounds of blank charges may be considered equivalent to one with projectile, the fact being noted in the column for "Remarks."
† Note the amount and position of scoring, if any, in addition to defects not already noted on this Memo.
‡ Quote the number on the article.
§ Fill in here the date of any repair ordered.

[redacted]

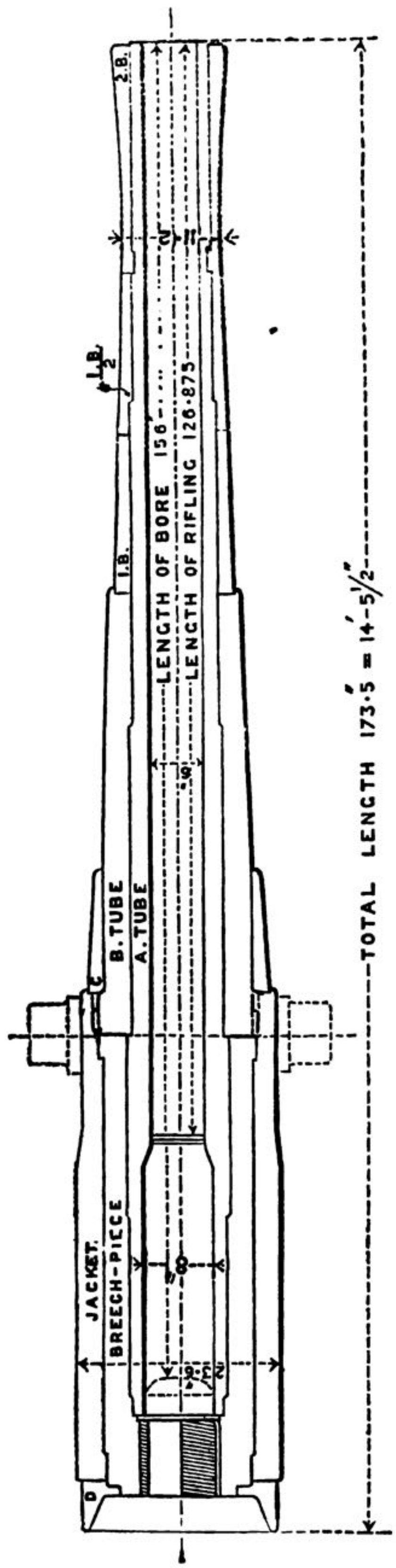
(Fourth Page.)

Record of Rounds Fired.

Returned from	Date.	Number of Rounds Fired.				Remarks.
		Blank (Reduced).	With Projectile.			
			Proof.	Full.	Reduced.	

Note.—Inside sheets are supplied to continue this record as required.

CHAP. III.



6-INCH, 5 TONS. MARK IV. STEEL.
Scale $\frac{1}{24}$.

(*Fifth Page.*)

Ordnance, B.L., 6-*inch*, 5 *tons. Mark IV. Steel.*

The gun is composed of nine parts, all of steel, viz.:—the A tube, over which is shrunk the breech-piece receiving the breech-screw, and interlocked with the A tube; in front of the breech-piece are shrunk the B tube, and the 1 B, $\frac{1B}{2}$, and 2 B hoops extending to the muzzle; over the breech-piece is shrunk the jacket with trunnions, being interlocked with the B tube; the C hoop is shrunk in front of the trunnions and the D hoop or hood is attached by screws to the breech. The chamber is cylindrical, terminating in front in a curved slope. The gun is rifled on the polygroove system (M.B. section) with 24 grooves, and a twist increasing from 1 turn in 120 calibres at breech to 1 turn in 35 calibres at 61·75 inches from the muzzle, the remainder being uniform 1 in 35 calibres.

After firing, a shifting of the hoops may take place; if this is but slight, and does not increase, it may be disregarded; if otherwise, the gun should be provisionally condemned.

A crack in the steel barrel is sufficient to warrant provisional condemnation, but care must be taken to discriminate between a crack and a superficial streak.

This gun should be examined after each series of 100 rounds with projectiles.

The condition of the bore can be ascertained by taking impressions of it in gutta-percha; if no instruments for this purpose are in charge, requisition should be made on the Ordnance Store Department.

Full directions for the examination of ordnance are given in the Equipment Regulations, and in the Instructions for the Examination and Repair of Naval Ordnance.

(*Sixth Page.*)

Instructions.

This Memo. is intended to present a complete history of the gun from the date of its issue from the Royal Gun Factory to its final return into store.

It is to be always kept with the gun, and to accompany it when returned into store.

The number of rounds fired, including blank charges, to be entered by the Officer in charge, at the conclusion of each day's practice, so that an accurate record of the firing may always be kept up.

The results of any examination whilst on service will be added by the Officer, or other Examiner, who performs the duty, and the rounds totalled up to such date.

If at any time this Memorandum of Examination be lost or damaged a duplicate can be obtained from the Superintendent, Royal Gun Factory, by whom also inside sheets for continuation of the record of the rounds fired will be suppled on application.

W. O. FORM, 1473.

W.O. Form 1473.

*Royal Artillery*________________ *District,*________________ *Station.*________________ 188

RETURN OF ORDNANCE WHICH HAVE FIRED THE PRESCRIBED NUMBER OF ROUNDS SINCE PREVIOUS EXAMINATION.

Nature.	Descriptive Marks.			Weight.				Number of rounds fired		Name of Battery where mounted.	When next required for practice.	Number of rounds remaining to be fired this year.	Remarks.
	Number on Trunnion.	Letter.	Date.	Tons.	Cwt.	Qrs.	Lbs.	Since last Examination.	Total.				

The
Director of Artillery and Stores,
War Office, Pall Mall, S.W.

____
In Charge of Guns at Battery.

____
Commanding the District.

*** State if any impression is sent, or if there is no person at hand to take one.**
† In the case of smooth-bore guns this return should be sent direct to the Superintendent, Royal Gun Factories.

Number of Rounds

Brigade.

Army Form G 872
(late W.O. Form 1476).

f	Sentence on Gun.			REMARKS *
	↑	R	+	
Bottom.	Serviceable	Repairable	Unserviceable	

e of this Return.

To be signed by the Commanding Officer at the end within.

g

attery.

AN ANNUAL RETURN** of

Army Form G 869.

Service.

18

Descriptive M[illegible]					Number of rounds fired with projectiles.			Received from		Returned or issued to		REMARKS.†
Foundry.				[illegible]e.								
Number on Trunnion.	Letters.	Date.	Register Number	[illegible]one-[illegible]g. [illegible]ugh-[illegible]g. [illegible]able.	Previous to last report.	Since last report.	Total.	Station, &c.	Date.	Station, &c.	Date.	

[illegible] Gun has been re-vented at the station since the last return, the date [illegible]ting and description of vent should be inserted in this column.

W. O. FORM, 1473.

W.O. Form 1473.

*Royal Artillery*________________*District,*________________*Station,*________________188

RETURN OF ORDNANCE WHICH HAVE FIRED THE PRESCRIBED NUMBER OF ROUNDS SINCE PREVIOUS EXAMINATION.

Nature.	Descriptive Marks.			Weight.				Number of rounds fired		Name of Battery where mounted.	When next required for practice.	Number of rounds remaining to be fired this year.	Remarks.
	Number on Trunnion.	Letter.	Date.	Tons.	Cwt.	Qrs.	Lbs.	Since last Examination.	Total.				

The
Director of Artillery and Stores,
War Office, Pall Mall, S.W.

____
In Charge of Guns at Battery.

____
Commanding the District.

* State if any impression is sent, or if there is no person at hand to take one.
† In the case of smooth-bore guns this return should be sent direct to the Superintendent, Royal Gun Factories.

Number of Rounds

Brigade.

Army Form G 872
(late W.O. Form 1476).

f	Sentence on Gun.			Remarks *
	↑	R	+	
	Serviceable	Repairable	Unserviceable	

e of this Return.

g
attery.

To be signed by the Commanding Officer at the end within.

AN ANired from each Gun.

Army Form G. 872
(late W.O. Form 1476.)

_______________ 18

Description			to date n. s. iced and lank.		Received from		Returned or Issued to¶		Whether Memo. of Examination is in possession of O.C., and completed to date.	‡ REMARKS.
Register Number.	Mark.	Initial of Factory and Date; also enter letter D if on Gun.§	Since.	Total.	Station, &c.	Date.	Station, &c.	Date.		

** If any 2·5" whether serviceable for practice, with, or without, gas-checks.
† If repairable, return.
‡ When any gu The preparation of the gun for any additional fitting, such as index
plates or r
§ This letter wi
|| With those gu
¶ To include an

Army Form G 869.

Service.

_______________ 18____

Descriptive M					Number of rounds fired with projectiles.			Received from		Returned or issued to		Remarks.†
Foundry.			Register Number	e. one- g. ugh- g. able.								
Number on Trunnion.	Letters.	Date.			Previous to last report.	Since last report.	Total.	Station, &c.	Date.	Station, &c.	Date.	

any Gun has been re-vented at the station since the last return, the date
* Should a G of venting and description of vent should be inserted in this column.
‡ Give name

Army Form G 925.

AN ' Rounds fired from each Gun.

_______________18

Description of Gun.						ɘd to date urn.		Received from		Returned or issued.*		Sentence on Gun and Fittings.†	REMARKS. ‡
				Nominal Weight.		iles. ɘed and Blank.							
Register Number.	Mark.	Initial of Factory and Date.	Nature.	Tons.	cwt.	Since.	Total.	Station, &c.	Date.	Station, &c.	Date.		

¶ Note the amount and | removed since the date of the previous annual return.
§ Insert Number which ʬ. of Examination is present with each gun, and completed to date.
† If repairable, give natu
repair has been ca

APPENDIX.

APPENDIX.

Instructions for fitting the Reflecting Sights to Guns mounted on Moncrieff Carriages, Mark II.

Mirror sights.

The gun must first be run up into firing position. The axis of the bore of the gun is then brought into and fixed in a horizontal plane. A "plumb-bob" is now dropped from the centre of the face of the right trunnion, and a vertical line is scribed on the side of the rocker. This line need only start at about 22 inches from the lower edge of the rocker, and be continued upwards for a distance of 12 inches. A distance of 66·275 inches is then measured down this vertical line, starting from the axis of the trunnions. Through the point thus obtained a horizontal line is scribed on the side of the rocker. This line should extend from the right hand edge of the rocker to within about 14 inches from the left edge. Two points are then marked on this horizontal line, one at a distance of 17·75 inches to the left, the other at 22·75 inches to the right of the vertical line.* The "graduated bar" for lower sight is now to be temporarily wedged or clamped to the side of the rocker in such a position that its lower right and left hand corners shall cover the points marked on the side of the rocker. The sliding or lower mirror is then clamped to the bar, with the pointer or reader reading truly at zero. A spot is now marked on the surface of this lower mirror (with ink or chalk) in such a position that it shall be central to the top and bottom of the glass, but at a distance out from the side of the rocker of 4·5 inches.

A point must now be fixed at some convenient distance in front of the gun, in such a position that when sighted from the tangent sight at zero it shall correspond exactly. In the event of the firing position of the gun being such that there is no suitable place upon which this point can be fixed, a spot or any distant object may be selected to take its place: in this case all sight lines will be sighted on this chosen spot, the distance of which would render its crosses undistinguishable. Should there, however, be nothing decisive to take for a sighting point, the gun must be trained inland until a distant object can be seen, in the line of gun, when its axis is at zero, but the fixing of the sights with the gun out of its firing position should not be resorted to unless absolutely necessary, as the correctness of reflecting sights depends entirely upon the gun, when run up, retaining its relative position to the rocker and horizontal plane, as it did at the time the bar was fixed. This can only occur when the racers are truly in the one horizontal plane; and should the gun have to be trained round in order to fix the sights, the level of the surface of the racers at the determined position of the carriage, must be checked by the level of the racers at the firing position of carriage, and any discrepancy rectified or allowed for.

The "upper" or trunnion reflector, the cross lines on which are already marked, is then fixed to the trunnion by the eye bolt, and

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* A short line is then scribed on the upper surface of the bar, at a distance of 12·125 inches from its upper and left-hand end. This line represents a temporary zero line.

gradually turned until the reflection of its own horizontal cross lines and the fixed point in front of the gun shall be seen to cover each other. As soon as the angle of the trunnion reflector has been adjusted to fulfil these conditions, the reflector is firmly fixed against the trunnion, its position on the trunnion marked, as also the position of the screw hole for the attachment. The reflections of the centres of the vertical cross lines on trunnion reflector and the fixed point in front of the gun must now be observed, and if they do not cover each other, and also the spot on lower mirror, this spot must be removed and another placed in such position, to the right or left, that covering may take place.

The tangent sight of the gun is now raised and clamped at 10 degrees elevation, and the gun elevated; the lower mirror is now shifted to the right and clamped in the position where the reflections of the horizontal cross line of trunnion reflector and of the fixed point are seen to cover each other and also the spot on its glass. The reflections of the centres of the vertical cross lines must now be observed, and if they also cover each other and the spot, the angle of deflection, that is the angle between the side of the rocker and the face of bar, is correct. If these lines do not cover, then another smaller spot must be placed in such position that it is covered by the reflections of the centres of both vertical lines.

The holes for attachment are next drilled, the bar removed, the holes tapped, and finally the bar firmly bolted to side of rocker. The squares are chipped off the heads of bolts, the heads filed smooth and their corresponding holes in the bar marked. At the same time the trunnion reflector is removed, the holes for attachment bored and tapped, and finally the reflector screwed firmly to the trunnion.

The tangent sight is now lowered to zero, the gun depressed until the line of sight corresponds to the fixed point in front of muzzle. The lower mirror is cleaned of its spots and brought into such position that the reflections of the fixed point and centre of trunnion reflector shall cover each other as near the centre of the lower mirror as possible. The centre of the reflection where they cover each other is marked on lower mirror by a spot, and through this spot cross lines are drawn in ink across the face of the glass, corresponding to the reflection of the cross lines of the trunnion reflector. The zero line is now scribed from the pointer upon the face of the bar. The gun is next elevated 10 degrees by sighting over tangent sight to the fixed point, the lower mirror is then shifted to the right and clamped in such position that the centre of its temporary cross lines is covered by the reflections of the centre of the cross lines in trunnion reflector and the fixed point in front of gun: the 10 degree line is then scribed from the pointer upon the face of the bar. The gun is now laid for 9 degrees elevation (by sighting as previously explained for 10 degrees), the lower mirror brought to meet the reflected horizontal cross lines of trunnion reflector and fixed point in front of gun, and the 9 degree line scribed on face of bar. The same process is then gone through to obtain each degree of elevation until the zero line is again reached. The gun is now depressed 1 degree, its position being correctly ascertained by means of a straight edge and spirit level placed in the bore; the lower mirror is then set to correspond with the reflected centres of the cross lines on the trunnion reflector and fixed point, and the line representing 1 degree of depression scribed on the bar. The gun is then depressed 2 degrees, by the assistance of the straight edge and spirit level, and a similar process to the last gone through for each succeeding degree until 5 degrees of depression have been scribed on the bar.

The glass of lower mirror is now taken out and the temporary cross

lines on front transferred to the back by scraping off with a knife and straight edge the mercury for their formation. The space between the degrees scribed on the bar is now divided into six equal parts, the lines and numbers of degrees are engraved and the lower mirror clamped in its zero position.

The gun is once more brought to zero, by a sight line from the tangent sight to the fixed point, and the glass of lower mirror, which has an amount of play between its edges and the brass frame, is set to meet the reflection of the trunnion reflector cross lines and fixed point: the spaces between the edges of the glass and frame are now packed in tightly with wood strips cut to fill the vacancies, care being taken that the cross lines are covered correctly with the fixed point in front of gun. The metal strips are then screwed down and the position of the cross lines on lower mirror marked on the level edges of the metal strips; so that in the event of a glass being broken a new one may be inserted in the proper position at once by means of these lines on the frame.

TABLE XLIV.

Tools required for adjustment of Moncrieff Reflecting Sights, Mark II.

Chisels	cross-cut	2
	hand	1
Drilling apparatus of any convenient character at the station		1
Drills, for screw holes for trunnion reflector, and for fixing the bars; to be made on the spot.		
Files	bastard, 12-inch, flat	1
	rough, 12-inch, flat	1
Hammer, hand		1
Levels	quadrant	1
	spirit	1
Plumb-bob and line		1
Straight edge (5 feet long)		1
Taps	$\frac{5}{8}$ inch	1
	$\frac{3}{4}$ "	1

Instructions for fixing Muzzle Derricks on R.M.L. Guns.

The following instructions have been drawn out for fixing bronze derricks to muzzles of heavy rifled guns:— Fixing muzzle derrick.

1st. Scribe a line upon the top of the chase from the vertical axis line on muzzle for a distance of about 12 inches towards the fore sight.

2nd. Remove the fixing screws and then try on the band; there may be a slight variation in the diameter of the muzzles of guns of the same nature, but if they are correct the bands would be seated as follows, viz.:—

Distance from face of muzzle to front edge of band .. { for 9″ M.L. guns $5\frac{1}{2}$″; for 10″, 11″, 12″, and $12\frac{1}{2}$″ guns, 6″.

Should the band not reach its seat, it will be necessary to ease it inside with a half-round file until it attains the required position. If, on

the other hand, the muzzle of the gun be small, the band must be pushed on as far as it will go.

3rd. When the band has been placed roughly in its position, turn it round until the vertical lines cut on the front and rear faces agree with the scribed line on muzzle mentioned above. When properly adjusted, give the front edge a few gentle taps all round with a piece of wood to drive it on the chase and thus fix it temporarily in position, but the relations of the lines must not be disturbed in so doing.

4th. Now mark off upon the chase the positions of the holes by means of a steel scriber, carefully guided around the interior of the screw holes, and then remove the band. Special attention must be paid to this operation.

5th. Dot round with a centre punch the circles just described, and centre each as nearly as possible ready for drilling.

6th. Erect the drilling apparatus and drill very carefully four holes, each $\frac{5}{10}$ in diameter and $\frac{1}{2}$ deep, to correspond with the plain points of the fixing screws.

Judgment must be exercised in drilling holes if required, so that they may be perfectly concentric with the dotted circles previously marked off.

At the chief stations, where artificers are at hand, drills can readily be prepared on the spot for this purpose, but in localities where these conveniences do not exist, the drills can be supplied on demand.

7th. After the holes are completed remove the drilling tackle, clean the surface of the chase, take off all "burrs" from the holes, and place the band in position; then insert the screws and send them home firmly and securely.

It will be necessary to adjust the bridge piece which supports the derrick when erected, so that the latter may be brought forward in order to maintain the required relation with the muzzle of the piece. It will be requisite first to level the gun and then to drop a plumb-line from the centre of the loop or eye at the top of the derrick, and the distance measured from the face of the muzzle to this line should be—

	″	
For 9″ M.L. gun	7·0	Limits of error, one inch minus or plus.
„ 10″ „	9·4	
„ 11″ „	10·3	
„ 12″ 25-ton „	10·45	
„ 12″ 35 „ „	11·5	
„ $12\frac{1}{2}$″ „	12·35	

Where the measurement does not comply with the above dimensions the lower side of bridge piece must be cut away and relieved until the proper overhang has been obtained.

Instructions for Deepening the Holes for Centre Hind Sights in R.M.L. Guns.

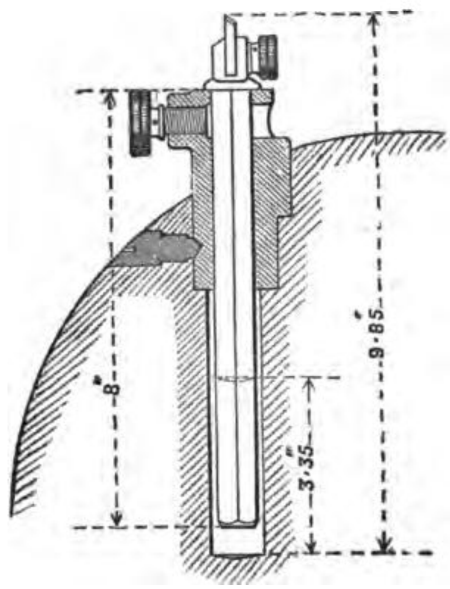
Deepening holes for centre hind sights.

Instructions for deepening the centre hind sight holes for 9″, 10″, 11″, and 12″ guns:—

Take out the metal sight socket and put the steel guide in its place. Erect the sighting machine drill frame (marked L in the tools for sighting ordnance), placing the drill in the steel guide and bringing the feed screw exactly to it. The drill and feed screw will not be quite perpendicular, but will be inclined at the correctional angle for the gun's deflection. Fasten the frame securely by a strong chain or rope to the gun, placing a block of hard wood under the tail.

The holes in the 12- and 18-ton guns can be sufficiently deepened with the shorter drill alone, but for those in the 25-ton guns it will be necessary to extend the hole further, and the longer drill must be substituted when the shorter one has drilled as deeply as the feed screw will drive it. It will be found convenient to mark the proper depth on the drill.

To use the machine, insert the drill, attach the ratchet brace, gently tighten up the feed screw, lubricate with oil, and turn the handle.



When the proper depth has been attained, remove the apparatus and steel guide, thoroughly clean out the hole and replace the socket; a small D will then be stamped in front of the hole.

Method of estimating Angles of Elevation and Descent.

The following table, arranged on the lines of Bashforth's, was devised by Mr. W. D. Niven for connecting together *velocity* and *angles* in the trajectory.

The letter D is used to denote *angles*, and the nomenclature and use of the table is the same as in Bashforth's, the formula being—

$$\frac{d^2}{w} D = D_V - D_v$$

in which D_V and D_v stand for the tabular values corresponding to velocities V and v respectively, and D the angle in Degrees through which the direction of motion turns while the velocity falls from V to v.

In order to determine the angle of elevation required for a particular gun at a particular range, for example, we have to know two things—the muzzle velocity and the remaining velocity after the tangent to the trajectory has turned through the angle of elevation. The first of course is known for the particular gun, the second has to be determined from the range given, by the aid of Bashforth.

Referring the angle of elevation and range to the horizontal through the muzzle, it is evident that the direction of motion has turned through the required angle when it reaches the highest point

of the trajectory, and if the trajectory be a *flat* one (as in the cases of "Direct" and "Curved" fire) so that the vertical component of resistance may be neglected, this point may be taken as the point of *half time*.

The method of proceeding therefore would be—first obtain from the range the time of flight (this will necessitate the use of both Bashforth's Tables), then halve this and deduce (from the Time and Velocity Table) the remaining velocity for this half time, then refer to the D Table for the angle turned through.

Example, Angle of Elevation for Range.

Required the angle of elevation for the 5″ B.L. at 2,000 yds.: M.V. =1780. Weight of proj.=50 lbs.

$$\frac{d^2}{w}=\frac{25}{50}=\frac{1}{2} \text{ (taking diam. of shell=calibre).}$$

For R.V. at 2,000 yds. (6,000 ft.)

$$(\tfrac{1}{2})\ 6{,}000 = S_V - S_v = 44360{\cdot}5 - S_v.$$
$$S_v = 41860{\cdot}5.$$

Tabular val. of 1165 = 41363·3]

$$\therefore v = 1165 \text{ (nearly).}$$

For time over 2,000 yds.

$$(\tfrac{1}{2})\ t = T_{1780} - T_{1165} = 2{\cdot}1 \text{ (nearly).}$$
$$\therefore t = 4{\cdot}2.$$

For R.V. at $\frac{1}{2}\,t$

$$(\tfrac{1}{2})\ 2{\cdot}1 = T_{1780} - T_v = 233{\cdot}0465 - T_v$$
$$T_v = 231{\cdot}9965$$

Tabular val. of 1402 = 231·9952

$$\therefore v \text{ (at half time)} = 1402 \text{ (nearly).}$$

For angle turned through between velocities 1780 and 1402—

$$(\tfrac{1}{2})\ D = D_{1780} - D_{1402} = 1{\cdot}2343$$
$$\therefore D = 2{\cdot}47 \text{ (nearly)}$$
$$= 2^\circ\ 28'.$$

Of course the calculation can be made more exact by taking decimals of a foot second in velocities on the principal of proportional parts, and the actual diameter and weight of shell instead of the calibre and reputed weight; but it is not proposed to discuss here the discrepancy shown by the Range Table—merely to illustrate the method of applying Mr. Niven's Table.

If there is any allowance for "jump" due to the mountings, this must be deducted from the above elevation before laying.

Angle of Descent at range.

To calculate now the angle of descent we have merely to apply the D table for the velocities at half time and end of range; in the above example 1402 and 1165.

$$\text{Thus } (\tfrac{1}{2})\ D = D_{1402} - D_{1165} = 1{\cdot}53 \text{ (nearly).}$$
$$\therefore D = 3{\cdot}06$$
$$= 3^\circ\ 3{\cdot}6'.$$

The calculations for high angle fire are of a more complicated nature. They will be found in Sladen's "Principles of Gunnery."

Table XIII.

Inclination and Velocity Table. $\frac{d^2}{w} D = D_r - D_v$.*

v.	0	1	2	3	4	5	6	7	8	9
f.s.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.
40	0	·4838	·9640	1·4407	1·9137	2·3830	2·8488	3·3110	3·7689	4·2240
41	4·6757	5·1240	5·5688	6·0101	6·4482	6·8828	7·3141	7·7421	8·1660	8·5874
42	9·0056	9·4207	9·8327	10·2410	10·6467	11·0496	11·4494	11·8462	12·2397	12·6306
43	13·0187	13·4039	13·7862	14·1652	14·5419	14·9159	15·2872	15·6557	16·0211	16·3843
44	16·7450	17·1030	17·4585	17·8110	18·1614	18·5094	18·8549	19·1980	19·5383	19·8766
45	20·2125	20·5460	20·8772	21·2054	21·5320	21·8565	22·1788	22·4989	22·8169	23·1327
46	23·4463	23·7578	24·0671	24·3736	24·6788	24·9821	25·2834	25·5827	25·8801	26·1756
47	26·4691	26·7607	27·0503	27·3376	27·6234	27·9075	28·1897	28·4702	28·7486	29·0254
48	29·3006	29·5739	29·8455	30·1151	30·3833	30·6498	30·9147	31·1779	31·4393	31·6993
49	31·9576	32·2143	32·4695	32·7227	32·9747	33·2253	33·4743	33·7219	33·9679	34·2125
50	34·4557	34·6973	34·9375	35·1761	35·4134	35·6493	35·8837	36·1167	36·3480	36·5783
51	36·8073	37·0349	37·2613	37·4862	37·7099	37·9323	38·1534	38·3731	38·5914	38·8086
52	39·0246	39·2394	39·4529	39·6651	39·8762	40·0860	40·2947	40·5022	40·7083	40·9135
53	41·1175	41·3204	41·5221	41·7225	41·9221	42·1205	42·3179	42·5142	42·7095	42·9037
54	43·0967	43·2887	43·4795	43·6690	43·8578	44·0456	44·2324	44·4182	44·6031	44·7870
55	44·9698	45·1516	45·3325	45·5122	45·6910	45·8689	46·0457	46·2217	46·3964	46·5705
56	46·7437	46·9160	47·0874	47·2581	47·4277	47·5965	47·7644	47·9314	48·0973	48·2625
57	48·4270	48·5906	48·7534	48·9153	49·0764	49·2368	49·3963	49·5551	49·7130	49·8701
58	50·0265	50·1822	50·3370	50·4909	50·6442	50·7968	50·9487	51·0999	51·2505	51·4002
59	51·5492	51·6975	51·8451	51·9917	52·1378	52·2832	52·4280	52·5721	52·7155	52·8583
60	53·0003	53·1417	53·2825	53·4224	53·5618	53·7005	53·8386	53·9761	54·1130	54·2492
61	54·3847	54·5196	54·6539	54·7875	54·9205	55·0529	55·1846	55·3158	55·4462	55·5761
62	55·7054	55·8342	55·9623	56·0899	56·2169	56·3433	56·4690	56·5942	56·7188	56·8428
63	56·9663	57·0891	57·2114	57·3330	57·4542	57·5749	57·6950	57·8146	57·9338	58·0523
64	58·1703	58·2878	58·4046	58·5209	58·6367	58·7521	58·8669	58·9832	59·0949	59·2081
65	59·3209	59·4332	59·5449	59·6562	59·7669	59·8772	59·9869	60·0961	60·2047	60·3130
66	60·4207	60·5280	60·6348	60·7411	60·8470	60·9523	61·0572	61·1616	61·2654	61·3688
67	61·4719	61·5744	61·6766	61·7783	61·8796	61·9804	62·0808	62·1807	62·2802	62·3793
68	62·4779	62·5761	62·6739	62·7711	62·8680	62·9646	63·0607	63·1565	63·2519	63·3468
69	63·4414	63·5356	63·6294	63·7227	63·8157	63·9084	64·0006	64·0924	64·1838	64·2749
70	64·3656	64·4559	64·5459	64·6356	64·7249	64·8137	64·9022	64·9903	65·0779	65·1652
71	65·2522	65·3388	65·4250	65·5107	65·5962	65·6813	65·7660	65·8504	65·9345	66·0182
72	66·1015	66·1845	66·2671	66·3494	66·4313	66·5128	66·5940	66·6749	66·7553	66·8355
73	66·9153	66·9949	67·0740	67·1529	67·2314	67·3096	67·3875	67·4649	67·5422	67·6190
74	67·6955	67·7717	67·8476	67·9231	67·9983	68·0733	68·1479	68·2223	68·2964	68·3702
75	68·4436	68·5168	68·5896	68·6620	68·7342	68·8062	68·8778	68·9492	69·0204	69·0912
76	69·1617	69·2318	69·3017	69·3712	69·4404	69·5094	69·5780	69·6464	69·7145	69·7823
77	69·8497	69·9169	69·9838	70·0503	70·1166	70·1826	70·2483	70·3137	70·3787	70·4436
78	70·5082	70·5725	70·6365	70·7004	70·7639	70·8271	70·8901	70·9527	71·0149	71·0770
79	71·1388	71·2004	71·2617	71·3228	71·3837	71·4442	71·5045	71·5646	71·6244	71·6839
80	71·7432	71·8023	71·8611	71·9196	71·9779	72·0359	72·0937	72·1513	72·2086	72·2656
81	72·3225	72·3791	72·4354	72·4915	72·5473	72·6030	72·6584	72·7135	72·7685	72·8232
82	72·8776	72·9317	72·9856	73·0393	73·0927	73·1458	73·1988	73·2514	73·3038	73·3560
83	73·4079	73·4596	73·5111	73·5622	73·6132	73·6639	73·7145	73·7648	73·8149	73·8647
84	73·9143	73·9636	74·0127	74·0615	74·1101	74·1585	74·2067	74·2546	74·3023	74·3498
85	74·3971	74·4441	74·4910	74·5376	74·5839	74·6301	74·6760	74·7217	74·7670	74·8123
86	74·8573	74·9022	74·9468	74·9912	75·0355	75·0795	75·1233	75·1669	75·2104	75·2536
87	75·2966	75·3395	75·3821	75·4246	75·4668	75·5089	75·5507	75·5924	75·6339	75·6752
88	75·7163	75·7572	75·7980	75·8385	75·8788	75·9190	75·9590	75·9988	76·0384	76·0778
89	76·1171	76·1562	76·1952	76·2339	76·2725	76·3109	76·3492	76·3873	76·4252	76·4629
90	76·5005	76·5379	76·5751	76·6121	76·6490	76·6857	76·7223	76·7588	76·7951	76·8312
91	76·8671	76·9029	76·9385	76·9739	77·0092	77·0444	77·0794	77·1142	77·1489	77·1835
92	77·2179	77·2522	77·2863	77·3203	77·3541	77·3878	77·4213	77·4547	77·4879	77·5210
93	77·5540	77·5868	77·6195	77·6520	77·6844	77·7167	77·7488	77·7807	77·8125	72·8442

* Calculated from the formula of W. D. Niven, Esq., M.A.

TABLE XIII.—*continued.*

Inclination and Velocity Table. $\frac{d^2}{w}$ $D=D_V-D_v$.

v.	0	1	2	3	4	5	6	7	8	9
f.s.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.
94	77·8757	77·9071	77·9384	77·9695	78·0005	78·0314	78·0622	78·0929	78·1234	78·1538
95	78·1841	78·2142	78·2442	78·2741	78·3039	78·3335	78·3630	78·3924	78·4216	78·4508
96	78·4798	78·5087	78·5375	78·5662	78·5947	78·6231	78·6514	78·6796	78·7076	78·7356
97	78·7634	78·7911	78·8188	78·8463	78·8736	78·9009	78·9280	78·9551	78·9819	79·0087
98	79·0354	79·0621	79·0886	79·1150	79·1413	79·1675	79·1936	79·2195	79·2954	79·2172
99	79·2968	79·3224	79·3478	79·3731	79·3983	79·4234	79·4484	79·4734	79·4982	79·5230
100	79·5476	79·5722	79·5966	79·6210	79·6453	79·6695	79·6935	79·7175	79·7414	79·7652
101	79·7889	79·8124	79·8359	79·8593	79·8826	79·9058	79·9289	79·9519	79·9748	79·9976
102	80·0203	80·0430	80·0655	80·0879	80·1102	80·1324	80·1544	80·1763	80·1981	80·2197
103	80·2412	80·2625	80·2837	80·3048	80·3256	80·3462	80·3667	80·3869	80·4071	80·4270
104	80·4466	80·4661	80·4854	80·5045	80·5234	80·5420	80·5605	80·5787	80·5967	80·6145
105	80·6321	80·6495	80·6667	80·6835	80·7003	80·7169	80·7333	80·7495	80·7654	80·7813
106	80·7970	80·8126	80·8280	80·8432	80·8583	80·8733	80·8882	80·9029	80·9175	80·9319
107	80·9463	80·9606	80·9747	80·9886	81·0026	81·0164	81·0301	81·0437	81·0573	81·0707
108	81·0841	61·0973	81·1105	81·1236	81·1366	81·1495	81·1624	81·1751	81·1877	81·2003
109	81·2129	81·2253	81·2377	81·2501	81·2623	81·2745	81·2866	81·2986	81·3105	81·3224
110	81·3342	81·3460	81·3578	81·3695	81·3811	81·3927	81·4042	81·4156	81·4269	81·4382
111	81·4495	81·4607	81·4719	81·4829	81·4939	81·5049	81·5159	81·5268	81·5377	81·5485
112	81·5593	81·5700	81·5807	81·5913	81·6019	81·6124	81·6230	81·6334	81·6439	81·6543
113	81·6647	81·6750	81·6853	81·6955	81·7057	81·7159	81·7260	81·7361	81·7462	81·7562
114	81·7662	81·7761	81·7861	81·7960	81·8058	81·8156	81·8254	81·8351	81·8448	81·8545
115	81·8641	81·8737	81·8833	81·8929	81·9024	81·9119	81·9213	81·9307	81·9401	81·9495
116	81·9588	81·9681	81·9774	81·9866	81·9958	82·0049	82·0141	82·0232	82·0322	82·0413
117	82·0503	82·0592	82·0682	82·0771	82·0860	82·0948	82·1036	82·1124	82·1212	82·1299
118	82·1386	82·1473	82·1559	82·1645	82·1731	82·1817	82·1902	82·1988	82·2073	82·2157
119	82·2241	82·2325	82·2408	82·2492	82·2575	82·2657	82·2740	82·2822	82·2903	82·2985
120	82·3066	82·3147	82·3228	82·3309	82·3389	82·3469	82·3549	82·3629	82·3708	82·3787
121	82·3865	82·3044	82·4022	82·4100	82·4178	82·4255	82·4333	82·4410	82·4486	82·4563
122	82·4639	82·4715	82·4790	82·4865	82·4940	82·5015	82·5090	82·5164	82·5238	82·5312
123	82·5386	82·5459	82·5533	82·5606	82·5679	82·5751	82·5824	82·5896	82·5968	82·6040
124	82·6112	82·6183	82·6254	82·6324	82·6395	82·6465	82·6535	82·6605	82·6675	82·6744
125	82·6814	82·6883	82·6951	82·7019	82·7088	82·7156	82·7224	82·7291	82·7359	82·7427
126	82·7494	82·7561	82·7627	82·7694	82·7760	82·7826	82·7892	82·7957	82·8023	82·8088
127	82·8153	82·8218	82·8283	82·8348	82·8412	82·8477	82·8541	82·8604	82·8668	82·8731
128	82·8794	82·8857	82·8920	82·8983	82·9045	82·9107	82·9169	82·9231	82·9292	82·9354
129	82·9415	82·9477	82·9538	82·9599	82·9660	82·9720	82·9780	82·9840	82·9900	82·9960
130	83·0019	83·0077	83·0138	83·0197	83·0256	83·0315	83·0373	83·0432	83·0490	83·0548
131	83·0606	83·0644	83·0721	83·0779	83·0836	83·0893	83·0950	83·1007	83·1063	83·1119
132	83·1176	83·1232	83·1288	83·1344	83·1400	83·1455	83·1511	83·1566	83·1621	83·1676
133	83·1730	83·1785	83·1840	83·1894	83·1949	83·2003	83·2057	83·2110	83·2164	83·2217
134	83·2271	83·2324	83·2377	83·2430	83·2483	83·2536	83·2588	83·2641	83·2693	83·2745
135	83·2797	83·2849	83·2900	83·2951	83·3003	83·3054	83·3105	83·3156	83·3207	83·3257
136	83·3308	83·3359	83·3409	83·3459	83·3509	83·3560	83·3609	83·3659	83·3709	83·3759
137	83·3808	83·3857	83·3906	83·3955	83·4004	83·4053	83·4101	83·4150	83·4198	83·4247
138	83·4295	83·4343	83·4391	83·4438	83·4486	83·4533	83·4581	83·4628	83·4676	83·4723
139	83·4770	83·4817	83·4863	83·4910	83·4956	83·5003	83·5049	83·5095	83·5141	83·5187
140	83·5233	83·5279	83·5325	83·5371	83·5417	83·5462	83·5507	83·5553	83·5598	83·5642
141	83·5687	83·5732	83·5777	83·5821	83·5866	83·5910	83·5954	83·5999	83·6043	83·6087
142	83·6130	83·6174	83·6218	83·6261	83·6305	83·6348	83·6392	83·6435	83·6478	83·6522
143	83·6565	83·6607	83·6650	83·6693	83·6735	83·6778	83·6820	83·6862	83·6904	83·6946
144	83·6988	83·7030	83·7072	83·7114	83·7156	83·7197	83·7239	83·7280	83·7321	83·7362
145	83·7403	83·7444	83·7485	83·7526	83·7567	83·7608	83·7649	83·7689	83·7730	83·7770
146	83·7810	83·7850	83·7891	83·7930	83·7970	83·8010	83·8050	83·8090	83·8130	83·8170
147	83·8209	83·8249	83·8288	83·8327	83·8366	83·8406	83·8445	83·8484	83·8522	83·8561
148	83·8600	83·8639	83·8677	83·8715	83·8754	83·8792	83·8830	83·8869	83·8907	83·8945
149	83·8983	83·9021	83·9059	83·9096	83·9134	83·9172	83·9209	83·9247	83·9285	83·9322
150	83·9359	83·9396	83·9433	83·9470	83·9507	83·9544	83·9581	83·9617	83·9654	83·9691
151	83·9727	83·9764	83·9800	83·9837	83·9873	83·9909	83·9946	83·9982	84·0018	84·0054
152	84·0090	84·0126	84·0161	84·0197	84·0233	84·0269	84·0304	84·0340	84·0375	84·0410
153	84·0446	84·0481	84·0516	84·0551	84·0587	84·0622	84·0657	84·0692	84·0727	84·0762

TABLE XIII.—*continued.*

Inclination and Velocity Table. $\frac{d^2}{w} D = D_V - D_v$

v.	0	1	2	3	4	5	6	7	8	9
f.s.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.
154	84·0796	84·0831	84·0866	84·0900	84·0935	84·0969	84·1004	84·1038	84·1072	84·1106
155	84·1140	84·1174	84·1208	84·1242	84·1276	84·1310	84·1344	84·1378	84·1412	84·1445
156	84·1479	84·1513	84·1546	84·1579	84·1613	84·1646	84·1679	84·1713	84·1746	84·1779
157	84·1812	84·1845	84·1878	84·1911	84·1943	84·1976	84·2009	84·2041	84·2074	84·2107
158	84·2139	84·2172	84·2204	84·2237	84·2269	84·2301	84·2333	84·2366	84·2398	84·2430
159	84·2461	84·2493	84·2525	84·2557	84·2588	84·2620	84·2652	84·2683	84·2715	84·2746
160	84·2778	84·2809	84·2840	84·2871	81·2902	84·2933	84·2965	84·2996	84·3027	84·30[illegible]8
161	84·3088	84·3119	84·3150	84·3180	84·3210	84·3242	84·3272	84·3302	84·3333	84·3363
162	84·3394	84·3424	84·3454	84·3484	84·3514	84·3544	84·3574	84·3604	84·3634	84·3664
163	84·3694	84·3724	84·3753	84·3783	84·3813	84·3843	84·3872	84·3902	84·3931	84·3960
164	84·3990	84·4019	84·4048	84·4078	84·4107	84·4136	84·4165	84·4194	84·4223	84·4252
165	84·4281	84·4310	84·4339	84·4367	84·4396	84·4425	84·4453	84·4482	84·4510	84·4539
166	84·4567	84·4595	84·4624	84·4652	84·4680	84·4709	84·4737	84·4765	84·4793	84·4821
167	84·4849	84·4877	84·4905	84·4933	84·4961	84·4988	84·5016	84·5044	84·5070	84·5099
168	84·5127	84·5154	84·5181	84·5209	84·5236	84·5263	84·5291	84·5318	84·5345	84·5372
169	84·5399	84·5426	84·5453	84·5480	84·5508	84·5534	84·5561	84·5588	84·5615	84·5641
170	84·5668	84·5695.	84·5721	84·5748	84·5775	84·5801	84·5828	84·5854	84·5880	84·5907
171	84·5933	84·5959	84·5985	84·6012	84·6038	84·6064	84·6090	84·6116	84·6142	84·6168
172	84·6193	84·6219	84·6245	84·6271	84·6297	84·6322	84·6348	84·6373	84·6399	84·6424
173	84·6449	84·6475	84·6500	84·6525	84·6550	84·6575	84·6601	84·6626	84·6651	84·6676
174	84·6701	84·6726	84·6750	84·6776	84·6800	84·6825	84·6850	84·6875	84·6899	84·6924
175	84·6948	84·6973	84·6997	84·7022	84·7046	84·7071	84·7095	84·7119	84·7144	84·7168
176	84·7192	84·7216	84·7240	84·7264	84·7288	84·7312	84·7336	84·7360	84·7384	84·7408
177	84·7432	84·7455	84·7479	84·7503	84·7526	84·7550	84·7574	84·7597	84·7621	84·7645
178	84·7668	84·7692	84·7715	84·7739	84·7762	84·7785	84·7809	84·7832	84·7855	84·7878
179	84·7902	84·7925	84·7948	84·7972	84·7994	84·8017	84·8040	84·8063	84·8086	84·8109
180	84·8131	84·8154	84·8177	84·8199	84·8222	84·8244	84·8267	84·8289	84·8312	84·8334
181	84·8357	84·8379	84·8401	84·8424	84·8446	84·8468	84·8490	84·8513	84·8535	84·8557
182	84·8579	84·8601	84·8623	84·8645	84·8667	84·8689	84·8711	84·8732	84·8754	84·8776
183	84·8798	84·8819	84·8841	84·8863	84·8884	84·8906	84·8927	84·8949	84·8970	84·8992
184	84·9013	84·9035	84·9056	84·9077	84·9099	84·9120	84·9141	84·9162	84·9184	84·9205
185	84·9226	84·9247	84·9268	84·9289	84·9310	84·9331	84·9351	84·9372	84·9393	84·9414
186	84·9435	84·9456	84·9476	84·9497	84·9518	84·9538	84·9559	84·9580	84·9600	84·9621
187	84·9641	84·9662	84·9682	84·9702	84·9723	84·9743	84·9763	84·9784	84·9804	84·9824
188	84·9845	84·9865	84·9885	84·9905	84·9925	84·9946	84·9966	84·9986	85·0006	85·0026
189	85·0045	85·0065	85·0085	85·0105	85·0125	85·0145	85·0165	85·0185	85·0204	85·0224
190	85·0244	85·0263	85·0283	85·0303	85·0322	85·0342	85·0361	85·0380	85·0400	85·0419
191	85·0438	85·0458	85·0477	85·0496	85·0515	85·0535	85·0554	85·0573	85·0592	85·0611
192	85·0630	85·0650	85·0669	85·0687	85·0706	85·0725	85·0744	85·0763	85·0782	85·0801
193	85·0820	85.0838	85·0857	85·0876	85·0895	85·0913	85·0932	85·0951	85·0969	85·0988
194	85·1006	85·1025	85·1043	85·1062	85·1080	85·1099	85·1117	85·1136	85·1154	85·1172
195	85·1190	85·1208	85·1227	85·1245	85·1263	85·1281	85·1299	85·1317	85·1335	85·1353
196	85·1371	85·1389	85·1407	85·1425	85·1443	85·1460	85·1478	85·1496	85·1514	85·1531
197	85·1549	85·1567	85·1584	85·1602	85·1619	85·1637	85·1654	85·1672	85·1689	85·1707
198	85·1724	85·1741	85·1759	85·1776	85·1793	85.1810	85·1827	85·1844	85·1862	85·1879
199	85·1896	85·1913	85·1930	85·1947	85·1964	85·1981	85·1998	85·2014	85·2031	85·2048
200	85·2065	85·2081	85·2098	85·2115	85·2131	85·2148	85·2165	85·2181	85·2198	85·2214
201	85·2231	85·2247	85·2264	85·2280	85·2296	85·2313	85·2329	85·2346	85·2362	85·2378
202	85·2394	85·2411	85·2427	85·2443	85·2459	85·2476	85·2492	85·2507	85·2524	85·2540
203	85·2556	85·2572	85·2588	85·2604	85·2620	85·2635	85·2651	85·2667	85·2682	85·2698
204	85·2714	85·2729	85·2745	85·2760	85·2776	85·2791	85·2807	85·2822	85·2838	85·2853
205	85·2868	85·2884	85·2899	85·2915	85·2930	85·2945	85·2960	85·2975	85·2990	85·3005
206	85·3020	85·3035	85·3051	85·3066	85·3081	85·3095	85·3110	85·3125	85·3140	85·3155
207	85·3170	85·3184	85·3199	85·3214	85·3229	85·3244	85·3258	85·3273	85·3287	85·3302
208	85·3316	85·3331	85·3345	85·3360	85·3373	85·3388	85·3403	85·3417	85·3431	85·3446
209	85·3460	85·3474	85·3488	85·3503	85·3517	85·3531	85·3545	85·3559	85·3573	85·3587
210	85·3601	85·3615	85·3629	85·3643	85·3657	85·3671	85·3685	85·3698	85·3712	85·3726
211	85·3740	85·3754	85·3767	85·3781	85·3795	85·3808	85·3822	85·3836	85·3849	85·3863
212	85·3876	85·3890	85·3903	85·3917	85·3930	85·3943	85·3957	85·3970	85·3983	85·3996
213	85·4010	85·4023	85·4036	85·4049	85·4063	85·4076	85·4089	85.4102	85·4115	85·4128

TABLE XIII.—*continued.*

Inclination and Velocity Table. $\frac{d^3}{w} D = D_v - D_V$

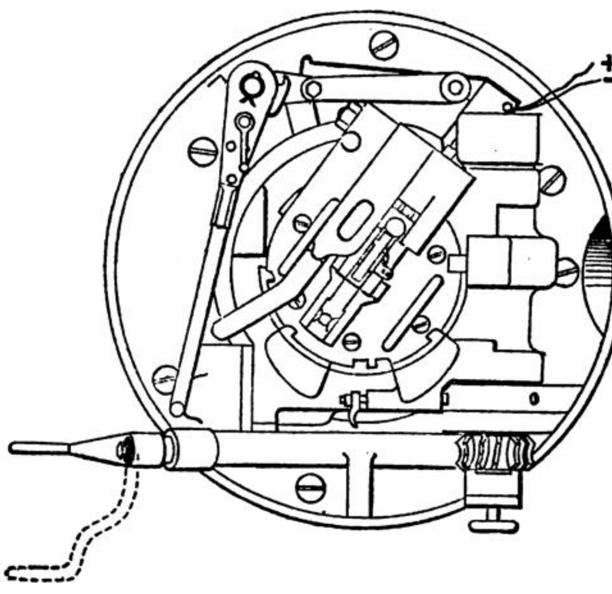
v.	0	1	2	3	4	5	6	7	8	9
f.s.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.
214	85·4141	85·4154	85·4167	85·4180	85·4193	85·4206	85·4219	85·4232	85·4245	85·4258
215	85·4271	85·4284	85·4297	85·4309	85·4322	85·4335	85·4348	85·4360	85·4373	85·4385
216	85·4398	85·4411	85·4423	85·4436	85·4448	85·4461	85·4473	85·4485	85·4498	85·4510
217	85·4523	85·4535	85·4547	85·4560	85·4572	85·4584	85·4597	85·4609	85·4621	85·4633
218	85·4645	85·4658	85·4670	85·4682	85·4694	85·4706	85·4718	85·4730	85·4742	85·4754
219	85·4766	85·4778	85·4790	85·4802	85·4814	85·4825	85·4837	85·4849	85·4861	85·4873
220	85·4885	85·4896	85·4908	85·4920	85·4932	85·4943	85·4955	85·4967	85·4978	85·4990
221	85·5001	85·5013	85·5024	85·5036	85·5047	85·5059	85·5070	85·5082	85·5093	85·5105
222	85·5116	85·5128	85·5139	85·5150	85·5162	86·5173	85·5184	85·5195	85·5207	85·5218
223	85·5229	85·5240	85·5251	85·5262	85·5273	85·5285	85·5296	85·5307	85·5318	85·5329
224	85·5340	85·5351	85·5362	85·5373	85·5384	85·5394	85·5405	85·5416	85·5427	85·5438
225	85·5449	85·5460	85·5470	86·5481	85·5492	85·5502	85·5513	85·5524	85·5534	85·5545
226	85·5556	85·5566	85·5577	85·5588	85·5598	85·5609	85·5619	85·5630	85·5640	85·5651
227	85·5661	85·5672	85·5682	85·5693	85·5703	85·5713	85·5724	85·5734	85·5744	85·5755
228	85·5765	85·5775	85·5785	85·5796	85·5806	85·5816	85·5826	85·5836	85·5846	85·5856
229	85·5966	85·5876	85·5886	85·5896	85·5906	85·5916	85·5926	85·5936	85·5946	85·5956
230	85·5966	85·5976	85·5986	85·5996	85·6006	85·6015	85·6025	85·6035	85·6045	85·6055
231	85·6064	85·6074	85·6084	85·6094	85·6103	85·6113	85·6123	85·6132	85·6142	85·6151
232	85·6161	85·6171	85·6180	85·6190	85·6199	85·6209	85·6218	85·6228	85·6237	85·6247
233	85·6256	85·6265	85·6275	85·6284	85·6294	85·6303	85·6312	85·6321	85·6331	85·6340
234	85·6349	85·6358	85·6367	85·6377	85·6386	85·6395	85·6404	85·6413	85·6422	85·6431
235	85·6441	85·6450	85·6459	85·6468	85·6477	85·6486	85·6495	85·6504	85·6513	85·6522
236	85·6531	85·6540	85·6549	85·6558	83·6566	85·6575	85·6584	85·6593	85·6602	85·6611
237	85·6619	85·6628	85·6637	85·6646	85·6654	85·6663	85·6672	85·6680	85·6689	85·6698
238	85·6706	85·6715	85·6724	85·6732	85·6741	85·6749	85·6758	85·6766	85·6775	85·6783
239	85·6792	85·6800	85·6809	85·6817	85·6826	85·6834	85·6843	85·6851	85·6859	85·6868
240	85·6876	85·6885	85·6893	85·6901	85·6909	85·6918	85·6926	85·6934	85·6942	85·6951
241	85·6959	85·6967	85·6975	85·6984	85·6992	85·7000	85·7008	85·7016	85·7024	85·7032
242	85·7041	85·7049	85·7057	85·7065	85·7073	85·7081	85·7089	85·7097	85·7105	85·7113
243	85·7121	85·7128	85·7136	85·7144	85·7152	85·7160	85·7168	85·7176	85·7184	85·7192
244	85·7200	85·7207	85·7215	85·7223	85·7231	85·7239	85·7246	85·7254	85·7262	85·7270
245	85·7277	85·7285	85·7293	85·7301	85·7308	85·7316	85·7324	85·7331	85·7339	85·7346
246	85·7354	85·7362	85·7369	85·7377	85·7384	85·7392	85·7399	85·7407	85·7414	85·7422
247	85·7429	85·7436	85·7444	85·7451	85·7459	85·7466	85·7474	85·7481	85·7488	85·7496
248	85·7503	85·7510	85·7517	85·7525	85·7532	85·7539	85·7547	85·7554	85·7561	85·7568
249	85·7575	85·7583	85·7590	85·7597	85·7604	85·7611	85·7618	85·7626	85·7633	85·7640

Remarks on Breech Mechanisms of B.L. Guns.

Some of the peculiarities of the different breech mechanisms as designed to meet the requirements of the time for each nature, have been briefly alluded to in the earlier part of the book, but perhaps hardly in sufficient detail to explain the object of each. The following description of one of the latest is therefore given somewhat at length, as from it the object and scope of the others may be better understood. The principles of the "safety" arrangements especially are similar, though the method of application is varied.

ORDNANCE, B.L. BREECH-CLOSING ARRANGEMENT, 9·2-INCH, MARK III.

Scale $\frac{1}{10}$.



The breech mechanism referred to is that of the 9·2-inch guns supplied to H.M.S. "Impérieuse," and is shown in woodcut above. This being only an outline drawing appears somewhat complicated, but the mechanism is really simple, though effecting a great deal. *9·2-inch mechanism for H.M.S. "Impérieuse."*

The features of novelty are:—

1. The "Controlled Carrier," by which the block is withdrawn and pushed home.
2. The "Stanhope lever," for turning the block (*vide* p. 277).
3. The safety arrangement connected with the percussion lock.
4. The safety electric firing arrangement.

The controlled carrier is necessitated partly by reason of the weight of breech-block which has to be worked on an incline when the gun is elevated; but principally (as the name implies) in consequence of the danger of allowing such a large mass as the breech-block and carrier to swing free, on board ship in a sea way.

The principal parts may be divided for descriptive purposes into—

(1.) *A bronze frame*, attached by fixing screws to the face of the breech, and constituting the bed of the whole mechanism.

(2.) *A bronze carrier*, partaking of both the forms of carrier applied to the lower natures, being a complete ring, but extended below in two horns to give a larger bearing for the breech-block when resting on it, and—

(3.) *A bronze plate*, attached to the end of the breech-block by fixing screws, and forming the bed of the cam lever.

The control mechanism. The carrier as usual hinges to the main bed by a vertical bolt on the right, but in this case the bolt becomes also a shaft for actuating the block and carrier. This is effected by a toothed pinion wheel, keyed on to the centre of the shaft, and whose head protrudes through the bearings, to gear into a rack let into the surface of the breech-block. The shaft is turned by means of a worm and wheel below. The worm is the termination of a horizontal shaft, carried by bearings on the main bed, and coming out on the left and inclined to the front for convenience in working the winch handle, which it takes. The worm wheel is carried on the lower end of the bolt shaft, being free to turn idly, unless keyed to it by means of a clutch, brought up by a small screw handle from beneath.

Alternative mechanism. This (clutch) arrangement is to enable the "control" action to be thrown out of gear: in which case the carrier and block swing free, as in the lower natures. A spring stop is also provided to take the place of the usual latch, to hold the carrier open. This will be seen in the cut at the bottom of the carrier. It is simply a spring bolt, which under ordinary circumstances is drawn back, and turned so as to be held back. When wanted (the control gear being thrown out) it is turned, and drops so as to press against the bearings of the main bed, and when the carrier is swung back it drops into a hole provided on the right. From this of course it must be again withdrawn when it is desired to close.

Action of control. The action of the control is as follows:—The breech-block having been turned to the withdrawing position, and the cam lever sufficiently lowered to start the withdrawing motion, the winch-handle is turned, and this, turning the bolt shaft, continues the withdrawing of the block, by means of the rack on its face. When the block is free of the breech, the end of the rack is reached, and then the effect of the pinion is to turn the whole, carrier and block, and swing it back on the shaft as a pivot. A reversal of the motion will of course reverse the process. The breech-block is fastened to the carrier by the usual three-armed clip, so until the carrier comes against the face of the breech, the rack motion cannot come into play in closing.

Safety mechanism for percussion firing. The safety arrangement for percussion firing is designed to prevent the tube being endangered if it is not properly home, and to ensure that it cannot be fired till the breech is properly closed, and the head of the tube supported.

To insert the tube, the lock has to be drawn back; and to fire it, the lock has to be pushed over again, so as to support the head of the tube, and bring the striker over the detonator. The end of the lock is slotted away on an incline, so that if the tube is fairly home it will pass over, and the insertion of the tube and subsequent covering of it by the lock can be partially effected by hand when the breech is open; but the lock cannot be pressed so far as to bring the striker into position. This is effected subsequently by the lowering of the cam lever when the breech is closed; and not till then, for a pin projecting from the face of the lever bed engages a slot in the under face of the lock, and limits its play. This pin is kept pressed out by a spring, but is capable of being withdrawn flush with its socket by a lever, one arm of which projects from the front face of the cam lever bed when the block is out. When the block is pushed home this arm is at first left undisturbed by

the carrier ring being here slotted away; but when the block is turned into the firing position the arm rides up an inclined plane on the carrier and the pin is withdrawn, allowing the lock its full travel.

On lowering the cam lever a slide connected with it (embedded in the bronze bearings) pushes the lock home into its firing position. The slide is actuated by the cam lever by means of a pin projecting from it engaging in a spiral groove cut in the face of the lever head; and the lock engages in the slide by its usual spring bolt, which drops into a hole in the slide. The slide is always in gear with the cam lever, so whenever this is raised or lowered, the slide is put in motion. But the lock does not engage in the slide unless the cam bed is pressed against the carrier—as when the breech is closed—for a pin (connected with the pin already mentioned for limiting the travel of the lock, and moving with it), stops the hole of the slide, so that the lock bolt does not drop into it when the breech is open.

Manipulation.

When the breech is open therefore the lock can be slid backwards and forwards, to admit the tube, and *partially* cover it, and the cam lever can be raised and lowered; but the lock will not be brought into the firing position. Further, the lock *must* be pressed by hand to partially cover the tube, or its bolt will not engage in the slide of the cam lever (being beyond its play), and the firing position will not be attained, even on closing. This provides for the contingency of a projecting tube, for it is left undisturbed, and cannot be fired.

Comparison with earlier designs.

In the earlier designs of percussion lock fittings the travel of the lock is similarly limited by a pin projecting from the face of the block, and which is withdrawn by a pin connected with it engaging in a slot in the inner surface of the carrier ring, which slot has an incline at its termination where the actuating pin travels on turning the block to the closed position. But the pushing of the lock into the firing position is effected *by the turning of the breech-block* at the same time; and the gun can be fired without lowering the lever into the locking position. The safety of the tube in case of projection is provided for by the projecting lock (or rather its spring bolt) coming in contact with an inclined face when the carrier is swung round to close. The incline is not sufficient to jam the tube, and a spring eases the jar; but until the tube is sufficiently home for the lock to pass over it, the breech cannot be closed at all.

Safety mechanism for electric firing.

The principle of the safety arrangement for electric firing is that the tube wires cannot be connected up till the breech is closed and the lock covering the tube.

The tube wires are first connected with a small junction piece, which is a separate store, and consists simply of two tapered metal pins, held about an inch apart by an ebonite block through which they pass. The pins project on both sides of the block, two ends being for the reception of the tube wires, the others for insertion into holes in a block on the gun.

This block is situated on the top of the bearings of the main bolt shaft, and in it are other holes, with binding screws, for the reception of the battery terminals. The holes for the battery terminals are of course in metallic connection with the holes for the pins of the junction piece, but when the breech is open these latter holes are stopped by ivory plugs.

The ivory plugs are carried on the end of a spring bolt, which presses them into the holes, and is then locked by a spring trigger. This prevents even force effecting the insertion of the junction pins.

The holes are opened by a sliding piece connected with the lock, the top of which, armed with a hook, projects above the cam bearings. When the breech-block is home and turned for locking, the hook of

the slide engages a hook on the end of the spring bolt, and its side pushes back the trigger. When the lever is lowered the lock is pressed into the firing position, as before explained, and the spring bolt with the ivory plugs is pulled away from the junction holes, and the tube can be connected up.

If the tube is not home, the lock, as before, remains unmoved, and the holes remain plugged.

Spring bolt for retaining lever.

A feature in the breech mechanism of all guns above the 8-inch (inclusive) is the spring stop provided in the lever bed to hold the lever in the vertical position during the operation of loading, &c. When it is desired to lower the lever for starting the block in withdrawing or for closing preliminary to firing, the button on the left of the lever has to be pressed in.

The latest proposal for electric firing is a separate slide, which takes the place of the percussion lock, and is similarly worked, but contains merely junctions for the battery terminals. The tube is altered in that the wires stop short at the head, and connection is made by the passage of the slide into the firing position, which is effected as when the percussion lock is used.

Facing Operations, R.B.L Guns.

Expanding guide.

In most of the operations connected with the breech bush a chamber guide is employed. This, in the cases of the 40-pr. and 7-inch, is an "expanding" one in two parts, necessitated by the fact of two blank rounds being required in these guns to set up the bush before finish boring. The bush being unfinished projects somewhat above the surface of the bore, and a solid block fitting the chamber could not pass it—there is no passage forward, of course.

Removing old bush.

Before inserting a new bush the old one will have to be removed. This is effected by a flat cutter passed through the slot of the spindle and keyed there by a wedge. This cutter is formed so as to cut away all the bush except the thread, which can then be pulled out of the threads in the gun in the form of wire. Care must be taken that the cutter is not damaging the threads in the gun. The cutter is formed so as to cut away the rim of the bush also, when the cut has been carried sufficiently deep to reach it; but generally speaking the rim twists off and comes away solid, in which case it should be removed and the cut proceeded with till the cutter no longer bites.

RANGE TABLES.

The following range tables have been corrected up to date by Major Anstruther, R.A., of the Director of Artillery Department in Woolwich, and Capt. May, R.N., but in some cases the muzzle velocity cannot be given, as formerly there were no records kept on this subject. It should be remembered that any change in the quality or "brand" of powder will affect the accuracy of range tables, and that the fuze scale also depends upon the standard conditions being strictly fulfilled. Range tables for the new B.L. guns have in some cases not yet been determined; all that have been determined are given. Where there are alternative charges the table has been made out for that first mentioned in heading.

Range Table for 17·72-inch R.M.L. Gun.

Based on Calculation, 28. 2. 83.

Charge, 450 lb. prism.[1] black.
Projectile, 2,000 lb.
Muzzle velocity, 1548 f.s.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes elevation increases or decreases the range by	5 minutes will alter point of impact vertically or laterally at each range.	Time of flight.	Fuze scale with 15 secs. wood time fuze estimated from practice with 12·5 inch.	
yards.	° ′	° ′	f.s.	yards.	yards.	secs.	yds.	tenths.
300	0 18	0 20	1515	71·0	0·43	0·61	260	1·0
400	0 25	0 28	1505	70·0	0·58	0·78	350	1·5
500	0 32	0 35	1495	69·0	0·72	0·95	440	2·0
600	0 39	0 42	1485	68·0	0·87	1·16	530	2·5
700	0 46	0 51	1475	66·9	1·01	1·37	620	3·0
800	0 53	0 58	1465	65·8	1·16	1·58	710	3·5
900	1 0	1 9	1455	64·7	1·31	1·80	800	4·0
1000	1 7	1 18	1445	63·6	1·45	1·98	890	4·5
1100	1 14	1 28	1435	62·5	1·60	2·16	980	5·0
1200	1 22	1 37	1425	61·9	1·74	2·34	1065	5·5
1300	1 30	1 46	1415	61·3	1·89	2·52	1155	6·0
1400	1 38	1 55	1405	60·7	2·03	2·70	1240	6·5
1500	1 46	2 4	1395	60·1	2·18	2·90	1330	7·0
1600	1 54	2 13	1385	59·5	2·32	3·14	1415	7·5
1700	2 2	2 25	1376	58·9	2·47	3·38	1500	8·0
1800	2 10	2 33	1367	58·3	2·61	3·62	1585	8·5
1900	2 18	2 44	1358	57·6	2·76	3·86	1670	9·0
2000	2 26	2 57	1349	56·9	2·91	4·10	1755	9·5
2100	2 34	3 7	1340	56·2	3·05	4·32	1840	10·0
2200	2 42	3 18	1331	55·5	3·20	4·54	1925	10·5
2300	2 51	3 29	1324	55·0	3·34	4·76	2010	11·0
2400	3 0	3 40	1315	54·5	3·49	4.98	2095	11·5
2500	3 9	3 52	1306	54·0	3·63	5·20	2180	12·0
2600	3 18	4 3	1297	53·5	3·78	5·46	2265	12·5
2700	3 27	4 14	1288	53·0	3·92	5·72	2350	13·0
2800	3 36	4 26	1279	52·5	4·07	5·98	2430	13·5
2900	3 45	4 37	1270	52·0	4·21	6·24	2515	14·0
3000	3 54	4 50	1262	51·5	4·36	6·50	2595	14·5
3100	4 3	5 3	1254	51·0	4·51	6·70	2675	15·0
3200	4 12	5 15	1246	50·5	4·65	6·90	2755	15·5
3300	4 21	5 28	1238	50·0	4·80	7·10	2835	16·0
3400	4 31	5 46	1230	48·5	4·94	7·30	2915	16·5
3500	4 41	6 2	1222	47·0	5·09	7·50	2990	17·0
3600	4 51	6 20	1214	45·5	5·23	7·73	3070	17·5
3700	5 2	6 40	1206	45·0	5·38	7·96	3150	18·0
3800	5 13	7 3	1199	44·5	5·52	8·19	3230	18·5
3900	5 24	7 27	1192	44·0	5·67	8·42	3310	19·0
4000	5 35	7 43	1185	43·6	5·81	8·65	3385	19·5
4100	5 46	7 46	1178	43·2	5·96	8·92	3465	20·0
4200	5 57	8 8	1171	42·8	6·11	9·19	3540	20·5
4300	6 8	8 20	1164	42·4	6·25	9·46	3620	21·0
4400	6 19	8 35	1157	42·0	6·40	9·73	3685	21·5
4500	6 30	8 54	1150	41·6	6·54	10·00	3775	22·0
4600	6 42	9 11	1143	41·0	6·69	10·26	3850	22·5
4700	6 54	9 33	1136	40·5	6·84	10·52	3925	23·0
4800	7 6	9 50	1129	40·0	6·98	10·78	4000	23·5
4900	7 18	10 10	1123	39·5	7·13	11·04	4080	24·0
5000	7 30	10 28	1117	39·0	7·27	11·30	4155	24·5
5100	7 42	10 47	1111	38·5	7·42	11·58	4230	25·0
5200	7 55	11 10	1105	37·7	7·56	11·86	4305	25·5
5300	8 8	11 40	1099	37·0	7·71	12·14	4380	26·0
5400	8 21	12 6	1093	36·3	7·85	12·42	4455	26·5
5500	8 34	12 35	1087	35·6	8·00	12·70	4530	27·0
5600	8 48	13 6	1081	34·8	8·14	12·98	4605	27·5
5700	9 2	13 37	1074	34·0	8·29	13·26	4680	28·0
5800	9 16	14 10	1069	33·2	8·43	13·54	4755	28·5
5900	9 31	14 47	1064	32·2	8·58	13·82	4830	29·0
6000	9 56	15 33	1059	31·2	8·73	14·10	4905	29·5
							4980	30·0

RANGE TABLE FOR 16-INCH R.M.L. GUNS OF 80 TONS. (Compiled 3/85.)

Based on Practice of 9. 10. 79., 20. 11. 79., and on Calculation.

Charge, 450 lb. prism.[1] black; gravimetric density, $\frac{32 \cdot 4}{0 \cdot 856}$.
Projectile, studless shell; weight, 1,700 lb.
Mounting, proof sleigh.
Jump, nil.
Muzzle velocity, 1,590 f.s.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high range must be known within	Remaining velocity.	Penetration wrought iron.	Time of Flight.	Fuse scale. 15 seconds M.L. wood time fuse. Estimated from practice with 12·5-inch gun.	
Yards.	° ′	° ′	1 in	yards.	f.s.	inches.	seconds.	yards.	tenths.
0					1590	24·9		260	1·0
100	0 6	0 6	515	858	1580	24·7	0·19	360	1·5
200	0 13	0 13	257	428	1569	24·5	0·38	460	2·0
300	0 20	0 20	170	283	1559	24·4	0·57	555	2·5
400	0 26	0 27	127	212	1549	24·2	0·76	650	3·0
								740	3·5
500	0 33	0 34	101	168	1539	24·0	0·96	830	4·0
600	0 40	0 42	82	136	1529	23·8	1·15	920	4·5
700	0 47	0 49	70	117	1519	23·6	1·35	1010	5·0
800	0 54	0 56	61	102	1509	23·5	1·54	1100	5·5
900	1 1	1 3	55	91	1499	23·3	1·74	1190	6·0
								1280	6·5
1000	1 8	1 11	48	80	1490	23·1	1·94	1370	7·0
1100	1 15	1 19	44	73	1480	22·9	2·14	1460	7·5
1200	1 22	1 27	40	66	1470	22·7	2·34	1550	8·0
1300	1 29	1 35	36	60	1460	22·6	2·55	1640	8·5
1400	1 37	1 44	33	55	1451	22·4	2·76	1730	9·0
								1815	9·5
1500	1 44	1 53	30	51	1441	22·2	2·97	1900	10·0
1600	1 52	2 1	28	47	1432	22·1	3·18	1990	10·5
1700	2 0	2 10	26	44	1422	21·9	3·39	2080	11·0
1800	2 8	2 19	25	41	1413	21·7	3·61	2170	11·5
1900	2 16	2 28	23	39	1403	21·6	3·83	2255	12·0
								2340	12·5
2000	2 24	2 37	22	36	1394	21·4	4·04	2425	13·0
2100	2 32	2 47	21	35	1385	21·3	4·26	2510	13·5
2200	2 40	2 57	19	33	1376	21·1	4·48	2595	14·0
2300	2 48	3 7	18	31	1367	21·0	4·69	2680	14·5
2400	2 56	3 17	17	29	1358	20·8	4·91	2765	15·0
								2850	15·5
2500	3 4	3 28	17	28	1349	20·7	5·13	2935	16·0
2600	3 12	3 39	16	26	1341	20·5	5·35	3020	16·5
2700	3 20	3 50	15	25	1332	20·4	5·58	3105	17·0
2800	3 29	4 0	14	24	1324	20·3	5·80	3190	17·5
2900	3 37	4 11	14	23	1315	20·1	6·03	3275	18·0
								3310	18·5
3000	3 46	4 21	13	22	1307	20·0	6·25	3440	19·0
3100	3 54	4 32	13	21	1299	19·8	6·48	3520	19·5
3200	4 3	4 43	12	20	1290	19·7	6·71	3600	20·0
3300	4 12	4 54	12	19	1282	19·5	6·94	3680	20·5
3400	4 21	5 5	11	19	1274	19·4	7·18	3760	21·0
								3840	21·5
3500	4 30	5 16	11	18	1266	19·3	7·41	3920	22·0
3600	4 39	5 27	10	17	1258	19·1	7·65	4000	22·5
3700	4 48	5 38	10	17	1251	19·0	7·89	4080	23·0
								4160	23·5

Range Table for 16-inch R.M.L. Guns of 80 tons—*continued.*

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high range must be known within	Remaining velocity.	Penetration wrought iron.	Time of Flight.	Fuze scale. 15 seconds M.L. wood time fuze. Estimated from practice with 12·5-inch gun.	
Yards.	° ′	° ′	1 in	yards.	f.s.	inches.	seconds.	yards.	tenths.
3800	4 57	5 50	9·8	16	1242	18·8	8·14	4240	24·0
3900	5 6	6 2	9·5	16	1235	18·7	8·39	4320	24·5
4000	5 15	6 14	9·2	15	1228	18·6	8·64	4400	25·0
4100	5 24	6 27	8·8	15	1220	18·5	8·88	4480	25·5
4200	5 33	6 40	8·6	14	1213	18·3	9·12	4560	26·0
								4640	26·5
4300	5 43	6 53	8·3	14	1206	18·2	9·37	4720	27·0
4400	5 53	7 6	8·0	13	1199	18·1	9·62	4800	27·5
4500	6 3	7 19	7·8	13	1192	18·0	9·87	4875	28·0
4600	6 13	7 33	7·6	13	1185	17·8	10·1	4950	28·5
4700	6 23	7 47	7·3	12	1178	17·7	10·3	5025	29·0
								5100	29·5
4800	6 33	8 1	7·1	12	1171	17·6	10·6	5775	30·0
4900	6 43	8 15	6·9	12	1165	17·5	10·9		
5000	6 53	8 29	6·7	11	1158	17·4	11·2		
5100	7 3	8 44	6·5	11	1152	17·3	11·4		
5200	7 13	8 59	6·3	11	1145	17·1	11·7		
5300	7 23	9 14	6·2	10	1139	17·0	12·0		
5400	7 34	9 29	6·0	10	1133	16·9	12·3		
5500	7 44	9 44	5·8	10	1126	16·8	12·5		
5600	7 55	10 0	5·7	9	1120	16·7	12·8		
5700	8 5	10 16	5·5	9	1114	16·6	13·0		
5800	8 16	10 32	5·4	9	1108	16·5	13·3		
5900	8 27	10 48	5·2	9	1102	16·4	13·5		
6000	8 38	11 4	5·1	9	1096	16·3	13·8		
6100	8 49	11 20	5·0	8	1091	16·2	14·1		
6200	9 0	11 36	4·9	8	1085	16·1	14·4		
6300	9 11	11 53	4·8	8	1080	16·0	14·7		
6400	9 22	12 10	4·6	8	1074	15·9	14·9		
6500	9 33	12 27	4·5	8	1069	15·9	15·2		
6600	9 44	12 45	4·4	7	1064	15·8	15·5		
6700	9 56	13 3	4·3	7	1059	15·7	15·8		
6800	10 8	13 21	4·2	7	1055	15·6	16·0		
6900	10 20	13 39	4·1	7	1050	15·5	16·3		
7000	10 32	13 57	4·0	7	1046	15·5	16·6		
7100	10 44	14 15	3·9	7	1042	15·4	16·9		
7200	10 56	14 34	3·8	6	1038	15·3	17·2		
7300	11 9	14 55	3·8	6	1034	15·3	17·5		
7400	11 21	15 12	3·7	6	1030	15·2	17·8		
7500	11 34	15 31	3·6	6	1027	15·1	18·0		
7600	11 47	15 50	3·5	6	1023	15·0	18·3		
7700	12 0	16 10	3·4	6	1020	15·0	18·6		
7800	12 13	16 30	3·4	6	1016	14·9	18·9		
7900	12 26	16 50	3·3	6	1013	14·8	19·2		
8000	12 39	17 10	3·2	5	1010	14·8	19·5		

Note.—The accuracy of this gun on a horizontal target may be taken as about equal to that of the 12·5-inch R.M.L. gun with 210 lbs. charge.

Owing to the lower angles of descent the vertical accuracy is somewhat greater at similar ranges.

Range Table for 16-inch R.M.L. Gun.

Based on Calculation.

Charge, 337½ lb. prism.[1], black.
Projectile, 1,700 lb.
Muzzle velocity, 1,354 f.s.
Gravimetric density, $\frac{43 \cdot 2}{0 \cdot 642}$.
Jump, 2 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, range must be known within	Time of Flight.	Fuze Scale. 15 seconds M.L. wood time fuze, estimated from practice with 12·5 inch gun.	
yards.	° ′	° ′	f.s.	1 in	yards.	seconds.	yards.	tenths.
0			1354				245	1·0
100	0 8	0 10	1345	344	573	0·20	330	1·5
200	0 18	0 21	1337	164	273	0·43	415	2·0
300	0 29	0 32	1328	107	179	0·62	500	2·5
400	0 40	0 43	1319	80	133	0·90	585	3·0
							670	3·5
500	0 51	0 55	1311	62	106	1·12	755	4·0
600	1 2	1 7	1303	51	86	1·40	840	4·5
700	1 13	1 18	1294	44	73	1·60	920	5·0
800	1 24	1 30	1286	38	64	1·83	1005	5·5
900	1 35	1 42	1278	34	56	2·06	1090	6·0
							1170	6·5
1000	1 46	1 54	1270	30	50	2·30	1250	7·0
1100	1 57	2 6	1262	27	45	2·52	1330	7·5
1200	2 8	2 18	1254	25	41	2·77	1410	8·0
1300	2 19	2 30	1247	23	38	3·0	1490	8·5
1400	2 30	2 43	1239	21	35	3·27	1570	9·0
							1650	9·5
1500	2 42	2 55	1232	20	33	3·50	1730	10·0
1600	2 54	3 8	1224	18	31	3·74	1810	10·5
1700	3 6	3 20	1217	17	29	3·99	1840	11·0
1800	3 18	3 33	1210	16	27	4·25	1970	11·5
1900	3 30	3 46	1203	15	25	4·49	2050	12·0
							2130	12·5
2000	3 42	4 0	1195	14	24	4·73	2210	13·0
2100	3 54	4 14	1189	13	22	5·0	2285	13·5
2200	4 6	4 28	1182	13	21	5·25	2360	14·0
2300	4 18	4 43	1175	12	20	5·50	2435	14·5
2400	4 30	4 57	1168	12	19	5·75	2510	15·0
							2585	15·5
2500	4 42	5 12	1161	11	18	6·0	2660	16·0
2600	4 55	5 27	1155	10	18	6·28	2735	16·5
2700	5 8	5 42	1148	10	17	6·53	2810	17·0
2800	5 21	5 57	1142	9·6	16	6·80	2885	17·5
2900	5 34	6 13	1136	9·2	15	7·05	2960	18·0
							3035	18·5
3000	5 47	6 29	1129	8·8	15	7·32	3110	19·0
3100	6 0	6 45	1123	8·4	14	7·60	3185	19·5
3200	6 13	7 1	1117	8·1	14	7·86	3260	20·0
3300	6 26	7 18	1110	7·8	13	8·15	3335	20·5
3400	6 40	7 35	1105	7·5	13	8·42	3410	21·0
							3480	21·5
3500	6 54	7 52	1099	7 2	12	8·70	3550	22·0
3600	7 8	8 9	1093	7·0	12	8·98	3620	22·5
3700	7 22	8 27	1087	6·7	11	9·24	3690	23·0
3800	7 36	8 45	1081	6·5	11	9·52	3760	23·5
3900	7 50	9 3	1076	6·3	10	9·80	3850	24·0
							3900	24·5
4000	8 4	9 23	1071	6·1	10	10·10	3980	25·0
							4060	25·5
							4130	26·0
							4200	26·5
							4270	27·0
							4340	27·5
							4410	28·0
							4480	28·5
							4550	29·0
							4620	29·5
							4690	30·0

Range Table for 12·5-inch R.M.L. Gun of 38 tons. (Revised 2/85.)
(Mark I. Unchambered.)

Based on Practice of 20. 4. 80, 22. 4. 80, 24. 8. 81, and 5. 9. 81.

Charge, 160 lbs. P². Gravimetric density, $\frac{30\cdot0}{\cdot924}$. Mounting, iron garrison.
Projectile, studless shell, with Mark II. gas-check, weight filled, 820 lbs.
Muzzle velocity, 1442 f.s. Jump, 5 minutes.

							50 per Cent. of Rounds fired should fall within				Fuze Scale, 15 secs. M.L. Wood Time Fuze.	
Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 ft. high, range must be known within	Remaining Velocity.	Penetration, Wrought-Iron.	Length.	Breadth.	Height.	Time of Flight.	Range.	Lengths of Fuze.
yds.	° ′	° ′	1 in	yds.	f.s.	inches.	yds.	yds.	feet.	secs.	yds.	
						17·5						
100	0 3	0 9	382	636	1430	17·3	19	0·04	0·1	0·21		
200	0 11	0 18	191	318	1418	17·1	19	0·08	0·3	0·42	260	1·0
300	0 19	0 26	132	220	1406	17·0	19	0·11	0·4	0·63	345	1·5
400	0 27	0 35	98	164	1395	16·8	19	0·15	0·6	0·85	430	2·0
500	0 36	0 44	78	130	1383	16·6	19	0·19	0·7	1·06	515	2·5
600	0 45	0 54	64	106	1372	16·5	19	0·23	0·9	1·28	600	3·0
700	0 54	1 4	54	89	1361	16·3	19	0·27	1·0	1·50	685	3·5
800	1 3	1 14	46	77	1350	16·2	19	0·31	1·2	1·72	770	4·0
900	1 12	1 24	41	68	1339	16·0	19	0·35	1·4	1·94	855	4·5
1000	1 21	1 34	37	61	1328	15·9	19	0·39	1·6	2·16	940	5·0
1100	1 30	1 44	33	55	1317	15·8	20	0·43	1·8	2·39	1020	5·5
1200	1 40	1 55	30	50	1307	15·7	20	0·48	2·0	2·62	1105	6·0
1300	1 50	2 6	28	46	1297	15·5	20	0·52	2·2	2·85	1185	6·5
1400	2 0	2 17	26	43	1286	15·4	20	0·57	2·4	3·08	1270	7·0
1500	2 10	2 28	24	40	1276	15·3	20	0·61	2·6	3·32	1350	7·5
1600	2 20	2 39	22	37	1266	15·1	20	0·66	2·8	3·56	1430	8·0
1700	2 30	2 51	20	34	1257	15·0	20	0·70	3·1	3·80	1515	8·5
1800	2 40	3 3	19	32	1247	14·9	20	0·75	3·3	4·05	1595	9·0
1900	2 50	3 15	18	30	1238	14·8	20	0·80	3·5	4·29	1675	9·5
2000	3 0	3 27	17	28	1228	14·7	20	0·84	3·7	4·55	1755	10·0
2100	3 10	3 39	16	26	1219	14·5	20	0·89	3·9	4·80	1835	10·5
2200	3 20	3 51	15	25	1210	14·4	20	0·95	4·1	5·05	1910	11·0
2300	3 30	4 3	14	24	1201	14·3	20	1·0	4·3	5·31	1990	11·5
2400	3 40	4 16	13	22	1192	14·2	20	1·0	4·6	5·57	2070	12·0
2500	3 50	4 29	13	21	1183	14·0	21	1·1	4·9	5·83	2150	12·5
2600	4 0	4 43	12	20	1174	13·9	21	1·1	5·2	6·09	2225	13·0
2700	4 11	4 57	12	19	1166	13·8	21	1·2	5·5	6·36	2305	13·5
2800	4 22	5 12	11	18	1159	13·7	21	1·2	5·8	6·62	2385	14·0
2900	4 33	5 27	10	17	1149	13·6	21	1·3	6·1	6·88	2465	14·5
3000	4 44	5 42	10	17	1141	13·5	21	1·3	6·4	7·15	2540	15·0
3100	4 55	5 57	10	13	1133	13·3	21	1·4	6·8	7·41	2620	15·5
3200	5 7	6 13	9·2	15	1126	13·2	22	1·5	7·1	7·68	2695	16·0
3300	5 19	6 29	8·8	15	1118	13·1	22	1·5	7·5	7·94	2775	16·5
3400	5 31	6 46	8·4	14	1110	13·0	22	1·6	7·9	8.21	2850	17·0
3500	5 43	7 3	8·1	13	1103	12·9	22	1·7	8·2	8·48	2925	17·5
3600	5 55	7 20	7·8	13	1096	12·8	22	1·7	8·6	8·75	3000	18·0
3700	6 8	7 37	7·5	12	1089	12·7	22	1·8	9·0	9·02	3075	18·5
3800	6 21	7 54	7·2	12	1082	12·6	22	1·9	9·4	9·30	3150	19·0
3900	6 34	8 11	7·0	12	1075	12·5	23	2·0	9·7	9·58	3225	19·5
4000	6 47	8 29	6·7	11	1068	12·4	23	2·0	10	9·86	3300	20·0
4100	7 0	8 37	6·5	11	1062	12·4	23	2·1	10	10·1	3375	20·5
4200	7 14	9 5	6·3	10	1056	12·3	23	2·2	11	10·4	3450	21·0
4300	7 27	9 23	6·1	10	1050	12·2	23	2·3	11	10·7	3525	21·5
4400	7 41	9 41	5·9	9·8	1044	12·1	24	2·3	12	11·0	3600	22·0
4500	7 54	10 0	5·7	9·4	1038	12·1	24	2·4	12	11·3	3675	22·5
4600	8 10	10 19	5·5	9·1	1033	12·0	24	2·5	13	11·6	3750	23·0
4700	8 23	10 38	5·3	8·9	1029	11·9	24	2·6	14	11·9	3825	23·5
4800	8 37	10 58	5·1	8·6	1024	11·8	24	2·7	14	12·2	3900	24·0
4900	8 50	11 18	5·0	8·3	1020	11·8	25	2·8	15	12·5	3975	24·5
5000	9 4	11 38	4·8	8·0	1016	11·7	25	2·9	16	12·8	4050	25·0
5100	9 18	11 59	4·7	7·8	1012	11·7				13·1	4125	25·5
5200	9 32	12 20	4·6	7·6	1008	11·6				13·4	4200	26·0
5300	9 46	12 42	4·4	7·4	1003	11·5				13·8	4275	26·5
5400	10 1	13 4	4·3	7·2	999	11·5				14·1	4350	27·0
5500	10 16	13 26	4·2	7·0	995	11·4				14·4	4420	27·5
5600	10 31	13 49	4·1	6·8	991	11·4				14·7	4495	28·0
5700	10 46	14 12	3·9	6·6	986	11·3				15·1	4570	28·5
5800	11 2	14 36	3·8	6·4	981	11·3				15·4	4645	29·0
5900	11 18	15 0	3·7	6·2	977	11·2				15·7	4720	29·5
6000	11 34	15 25	3·6	6·0	972	11·2				16·1	47[illegible]0	30·0

Range Table for 12·5-inch R.M.L. Gun, Mark I. (Compiled 3/85.)

Based on Practice 8. 9. 75 and 23. 1. 77 with 130 lbs. P² without stick, and on Calculation.

Charge, 130 lbs. P², with stick.
Muzzle velocity, 1352 f.s.
Gravimetric density, $\frac{30 \cdot 0}{\cdot 924}$.
Mounting, iron garrison.

Jump, 5 minutes.
Projectile, studless shell with automatic gas-check or studded shell with Mark I. or Mark II. gas-check. Wt. 820 lbs.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 ft. high, range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	Fifty per Cent. of Rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Fuze scale for 15 secs. M.L. wood, time estimated from practice in 12·5 inch gun with other charges.	
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	feet.	secs.	yds.	fuze.
0					1352	16·2						
100	0 4	0 10	354	590	1341	16·1	18	0·04	0·1	0·22	255	1·0
200	0 13	0 19	176	295	1330	16·0	18	0·07	0·3	0·44	340	1·5
300	0 23	0 29	118	198	1319	15·8	18	0·11	0·5	0·67	420	2·0
400	0 32	0 39	88	147	1309	15·7	18	0·15	0·6	0·89	505	2·5
500	0 42	0 49	70	117	1299	15·5	19	0·19	0·8	1·12	585	3·0
600	0 52	1 0	57	95	1289	15·4	19	0·23	1·0	1·35	670	3·5
700	1 2	1 10	49	82	1279	15·3	19	0·27	1·2	1·58	750	4·0
800	1 12	1 21	42	71	1269	15·2	19	0·31	1·3	1·82	830	4·5
900	1 22	1 32	37	62	1259	15·0	19	0·35	1·5	2·06	910	5·0
1000	1 32	1 43	33	56	1250	14·9	19	0·40	1·7	2·30	990	5·5
1100	1 42	1 54	30	50	1240	14·8	19	0·44	1·9	2·55	1065	6·0
1200	1 53	2 6	27	45	1230	14·7	19	0·49	2·1	2·80	1145	6·5
1300	2 3	2 18	25	41	1221	14·5	19	0·53	2·3	3·05	1225	7·0
1400	2 13	2 30	23	38	1212	14·4	19	0·58	2·5	3·30	1300	7·5
1500	2 24	2 43	21	35	1203	14·3	20	0·62	2·8	3·55	1380	8·0
1600	2 35	2 56	20	33	1194	14·2	20	0·67	3·0	3·81	1455	8·5
1700	2 46	3 9	18	30	1185	14·1	20	0·71	3·2	4·07	1535	9·0
1800	2 57	3 22	17	28	1176	13·9	20	0·76	3·5	4·33	1610	9·5
1900	3 8	3 36	16	26	1167	13·8	20	0·81	3·7	4·59	1690	10·0
2000	3 20	3 50	15	25	1158	13·7	20	0·86	3·9	4·85	1765	10·5
2100	3 31	4 4	14	23	1150	13·6	20	0·91	4·2	5·12	1845	11·0
2200	3 43	4 18	13	22	1142	13·5	20	0·96	4·5	5·38	1920	11·5
2300	3 55	4 33	13	21	1134	13·4	20	1·0	4·8	5·65	2000	12·0
2400	4 7	4 48	12	20	1126	13·3	20	1·1	5·0	5·91	2075	12·5
2500	4 19	5 3	11	19	1118	13·2	20	1·1	5·3	6·18	2150	13·0
2600	4 31	5 18	11	18	1110	13·1	20	1·2	5·5	6·44	2225	13·5
2700	4 43	5 34	10	17	1103	13·0	20	1·2	5·8	6·71	2300	14·0
2800	4 56	5 50	9·8	16	1096	12·9	20	1·3	6·1	6·93	2375	14·5
2900	5 9	6 6	9·3	16	1089	12·8	20	1·3	6·4	7·25	2450	15·0
3000	5 22	6 23	8·9	15	1082	12·7	20	1·4	6·7	7·52	2525	15·5
3100	5 35	6 40	8·5	14	1075	12·6	20	1·4	7·0	7·80	2600	16·0
3200	5 48	6 57	8·2	14	1068	12·5	20	1·5	7·3	8·08	2675	16·5
3300	6 1	7 14	7·8	13	1062	12·4	20	1·6	7·6	8·36	2745	17·0
3400	6 14	7 32	7·5	13	1056	12·3	20	1·6	8·0	8·64	2820	17·5
3500	6 28	7 50	7·2	12	1051	12·3	20	1·7	8·3	8·92	2895	18·0
3600	6 41	8 8	7·0	12	1046	12·2	20	1·8	8·6	9·20	2970	18·5
3700	6 55	8 26	6·7	11	1041	12·1	20	1·8	8·9	9·49	3040	19·0
3800	7 9	8 44	6·5	11	1036	12·0	20	1·9	9·2	9·78	3115	19·5
3900	7 23	9 3	6·3	10	1031	12·0	20	2·0	9·6	10·1	3190	20·0
4000	7 37	9 22	6·0	10	1026	11·9	20	2·1	10	10·4	3265	20·5
4100	7 51	9 41	5·9	10	1021	11·8	20	2·1	10	10·7	3340	21·0
4200	8 5	10 1	5·7	10	1016	11·8	20	2·2	11	11·0	3415	21·5
4300	8 19	10 21	5·5	9	1011	11·7	21	2·3	11	11·3	3490	22·0
4400	8 34	10 41	5·3	9	1006	11·6	21	2·4	12	11·6	3560	22·5
4500	8 49	11 1	5·1	9	1001	11·6	21	2·5	12	11·9	3635	23·0
4600	9 4	11 22	5·0	8	997	11·5	21	2·6	13	12·2	3710	23·5
4700	9 19	11 43	4·8	8	993	11·5	21	2·7	14	12·5	3785	24·0
4800	9 34	12 4	4·7	8	989	11·4	22	2·8	14	12·9	3860	24·5
4900	9 50	12 25	4·5	8	984	11·4	22	2·9	15	13·2	3930	25·0
5000	10 6	12 46	4·4	7	979	11·3	22	3·0	15	13·5	4005	25·5
5100	10 22	13 8	4·3	7	975	11·2				13·9	4080	26·0
5200	10 38	13 30	4·2	7	971	11·2				14·2	4155	26·5
5300	10 55	13 53	4·1	7	967	11·1				14·6	4225	27·0
5400	11 12	14 16	4·0	7	963	11·1				14·9	4300	27·5
5500	11 29	14 40	3·9	6	959	11·0				15·3	4375	28·0
5600	11 46	15 4	3·8	6	955	11·0				15·7	4450	28·5
5700	12 4	15 28	3·7	6	951	10·9				16·0	4520	29·0
5800	12 22	15 53	3·6	6	947	10·9				16·4	4595	29·5
5900	12 40	16 18	3·5	6	943	10·8				16·7	4670	30·0
6000	12 59	16 44	3·4	6	939	10·8				17·0		

Range Table for 12·5-inch R.M.L. Gun of 38 tons. Mark I.

Based on Calculation.

Charge, 100 lbs. P². Gravimetric density, $\frac{32 \cdot 0}{0 \cdot 867}$.

Jump, 3 minutes.
Projectile, common shell, weight 820 lbs., Mark II. gas-check.
Muzzle velocity, 1250 f.s.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an Object 10 ft. high Range must be known within.	Time of Flight.	Fuze Scale. Fifteen Seconds Wood M.L. Time Fuze.	
yds.	° ′	° ′	f.s.	1 in	yds.	secs.	yds.	ins.
0								
100	0 7	0 12	1240	286	447	0·24	240	1·0
200	0 17	0 22	1231	156	260	0·49	320	1·5
300	0 28	0 32	1222	107	179	0·74	395	2·0
400	0 39	0 43	1213	80	133	0·99	475	2·5
							550	3·0
							630	3·5
500	0 50	0 54	1204	64	106	1·24	705	4·0
600	1 1	1 6	1195	52	87	1·49	780	4·5
700	1 12	1 18	1187	44	73	1·74	860	5·0
800	1 23	1 30	1179	38	64	1·99	935	5·5
900	1 34	1 42	1171	34	56	2·24	1015	6·0
							1095	6·5
							1175	7·0
1000	1 45	1 54	1163	30	50	2·49	1250	7·5
1100	1 56	2 7	1155	27	45	2·75	1330	8·0
1200	2 7	2 20	1147	25	41	3·00	1405	8·5
1300	2 19	2 33	1139	22	38	3·26	1480	9·0
1400	2 31	2 47	1131	21	34	3·52	1555	9·5
							1635	10·0
1500	2 43	3 1	1123	19	31	3·78	1710	10·5
1600	2 55	3 15	1115	18	29	4·05	1785	11·0
1700	3 7	3 29	1107	16	27	4·32	1860	11·5
1800	3 19	3 43	1099	15	26	4·60	1935	12·0
1900	3 31	3 58	1092	14	24	4·88	2010	12·5
							2085	13·0
							2160	13·5
2000	3 44	4 13	1085	14	23	5·16	2230	14·0
2100	3 57	4 28	1078	13	21	5·44	2305	14·5
2200	4 10	4 44	1072	12	20	5·72	2375	15·0
2300	4 23	5 0	1066	11	19	6·0	2450	15·5
2400	4 36	5 16	1060	11	18	6·29	2520	16·0
							2595	16·5
2500	4 49	5 33	1054	10	17	6·58	2665	17·0
2600	5 3	5 50	1048	9·8	16	6·86	2740	17·5
2700	5 17	6 7	1043	9·3	16	7·15	2810	18·0
2800	5 31	6 25	1038	8·9	15	7·44	2885	18·5
2900	5 45	6 43	1033	8·5	14	7·73	2960	19·0
							3030	19·5
							3100	20·0
3000	5 59	7 1	1028	8·1	14	8·02	3170	20·5
3100	6 13	7 19	1023	7·8	13	8·31	3240	21·0
3200	6 27	7 38	1018	7·5	12	8·60	3310	21·5
3300	6 41	7 57	1013	7·2	12	8·9	3380	22·0
3400	6 55	8 16	1009	6·9	11	9·2	3450	22·5
							3520	23·0
3500	7 9	8 35	1005	6·6	11	9·5	3590	23·5
3600	7 23	8 54	1001	6·4	11	9·8	3655	24·0
3700	7 37	9 13	997	6·2	10	10·1	3725	24·5
3800	7 51	9 33	993	5·9	10	10·4	3790	25·0
3900	8 6	9 53	989	5·7	10	10·7	3860	25·5
							3925	26·0
							3985	26·5
4000	8 21	10 13	985	5·5	9	11·05	4050	27·0
4100	8 36	10 33	981	5·4	9	11·35	4120	27·5
4200	8 51	10 53	977	5·2	9	11·7	4190	28·0
4300	9 7	11 4	973	5·1	9	12·0	4255	28·5
4400	9 23	11 25	969	5·0	8	12·35	4325	29·0
							4390	29·5
4500	9 29	11 46	965	4·8	8	12·65	4460	30·0

Range Table for 12·5-inch R.M.L. Gun of 38 tons. (Mark II. chambered.) (Revised 2/85.)

Based on Practice of 30. and 31. 1. 82.

Charge, 210 lbs. prism.². Gravimetric density, $\frac{28 \cdot 57}{0 \cdot 972}$.
Projectile, studless Palliser shell, weight 820 lbs.
Muzzle velocity, 1575 f.s.
Mounting, iron, garrison, with hydraulic buffers.
Jump, 5 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an Object 10 ft. high Range must be known within	Remaining Velocity.	Penetration, Wrought-iron.	Fifty per Cent. of Rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Fuze scale for 15 Seconds M.L. Wood Time Fuze. Based on Practice. 22. 10. 84.	
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	ft.	secs.	yds.	fuze
100	0 1	0 7	490	820	1562	19·3	22	0·04	0·1	0·19	260	1·0
200	0 8	0 14	245	410	1549	19·1	22	0·07	0·3	0·38	350	1·5
300	0 15	0 21	164	273	1536	18·9	22	0·11	0·4	0·58	440	2·0
400	0 22	0 28	123	205	1523	18·7	22	0·14	0·6	0·78	530	2·5
500	0 29	0 35	98	164	1510	18·6	22	0·18	0·7	0·98	620	3·0
600	0 36	0 43	80	133	1497	18·4	22	0·21	0·9	1·18	710	3·5
700	0 43	0 51	67	112	1485	18·2	22	0·25	1·0	1·38	800	4·0
800	0 50	0 59	58	97	1473	18·1	22	0·29	1·2	1·59	890	4·5
900	0 58	1 7	51	86	1463	17·9	22	0·33	1·3	1·80	980	5·0
1000	1 6	1 15	46	76	1449	17·7	22	0·37	1·5	2·01	1065	5·5
1100	1 14	1 24	41	68	1437	17·6	22	0·41	1·6	2·22	1155	6·0
1200	1 22	1 33	37	62	1425	17·4	22	0·45	1·8	2·43	1240	6·5
1300	1 30	1 43	33	56	1413	17·2	22	0·49	2·0	2·64	1330	7·0
1400	1 38	1 53	30	51	1401	17·1	22	0·53	2·2	2·85	1415	7·5
1500	1 46	2 4	28	46	1389	16·9	22	0·58	2·4	3·07	1500	8·0
1600	1 54	2 15	25	42	1377	16·7	22	0·62	2·6	3·28	1585	8·5
1700	2 3	2 26	23	39	1366	16·6	22	0·67	2·8	3·50	1670	9·0
1800	2 12	2 37	22	36	1355	16·4	22	0·71	3·0	3·72	1755	9·5
1900	2 21	2 48	20	34	1344	16·3	22	0·76	3·2	3·94	1840	10·0
2000	2 30	2 59	19	32	1333	16·1	22	0·81	3·4	4·16	1925	10·5
2100	2 39	3 10	18	30	1322	16·0	22	0·86	3·7	4·38	2010	11·0
2200	2 48	3 20	17	29	1312	15·8	22	0·90	3·9	4·61	2095	11·5
2300	2 57	3 32	16	27	1302	15·7	22	0·95	4·1	4·84	2180	12·0
2400	3 6	3 44	15	26	1292	15·5	22	1·0	4·3	5·07	2265	12·5
2500	3 15	3 56	15	24	1282	15·4	22	1·0	4·6	5·30	2350	13·0
2600	3 24	4 8	14	23	1272	15·3	22	1·1	4·8	5·54	2430	13·5
2700	3 33	4 20	13	22	1262	15·2	22	1·1	5·0	5·78	2515	14·0
2800	3 43	4 32	13	21	1252	15·0	22	1·2	5·3	6·02	2595	14·5
2900	3 53	4 45	12	20	1242	14·9	22	1·2	5·5	6·27	2675	15·0
3000	4 3	4 58	12	19	1232	14·8	23	1·3	5·7	6·50	2755	15·5
3100	4 13	5 11	11	18	1223	14·7	23	1·3	6·0	6·77	2835	16·0
3200	4 23	5 24	11	18	1214	14·5	23	1·4	6·2	7·02	2915	16·5
3300	4 33	5 37	10	17	1205	14·4	23	1·4	6·5	7·27	2990	17·0
3400	4 43	5 50	9·8	16	1196	14·3	23	1·5	6·8	7·53	3070	17·5
3500	4 53	6 3	9·4	16	1187	14·2	23	1·5	7·1	7·79	3150	18·0
3600	5 4	6 17	9·1	15	1178	14·1	23	1·6	7·4	8·05	3230	18·5
3700	5 14	6 31	8·8	15	1169	13·9	23	1·7	7·8	8·31	3310	19·0
3800	5 25	6 45	8·5	14	1160	13·8	23	1·7	8·1	8·57	3385	19·5
3900	5 35	6 59	8·2	14	1152	13·7	23	1·8	8·4	8·84	3465	20·0
4000	5 46	7 14	7·9	13	1144	13·6	24	1·9	8·8	9·10	3540	20·5
4100	5 56	7 29	7·6	13	1136	13·5	24	2·0	9·2	9·37	3620	21·0
4200	6 7	7 44	7·4	12	1128	13·4	24	2·0	9·6	9·63	3695	21·5
4300	6 17	8 0	7·1	12	1120	13·3	24	2·1	10	9·90	3775	22·0
4400	6 28	8 16	6·9	11	1112	13·2	24	2·2	10	10·16	3850	22·5
4500	6 39	8 32	6·7	11	1105	13·1	25	2·3	11	10·43	3925	23·0
4600	6 50	8 49	6·4	11	1098	13·0	25	2·4	11	10·70	4000	23·5
4700	7 1	9 6	6·2	10	1091	12·9	25	2·5	12	10·97	4080	24·0
4800	7 12	9 22	6·1	10	1084	12·8	25	2·6	12	11·24	4155	24·5
4900	7 23	9 39	5·9	10	1077	12·7	26	2·7	13	11·52	4230	25·0
5000	7 34	9 46	5·8	10	1070	12·6	26	2·8	14	11·80	4305	25·5
5100	7 46	10 3	5·6	9	1064	12·5				12·08	4380	26·0
5200	7 57	10 21	5·5	9	1058	12·4				12·36	4455	26·5
5300	8 9	10 39	5·3	9	1053	12·3				12·64	4530	27·0
5400	8 21	10 57	5·2	9	1048	12·3				12·92	4605	27·5
5500	8 33	11 15	5·0	8	1043	12·2				13·23	4680	28·0
5600	8 45	11 34	4·9	8	1038	12·1				13·53	4755	28·5
5700	8 58	11 53	4·8	8	1033	12·0				13·82	4830	29·0
5800	9 11	12 12	4·7	8	1028	12·0				14·11	4905	29·5
5900	9 24	12 32	4·5	7	1023	11·9				14·41	4980	30·0
6000	9 37	12 52	4·4	7	1018	11·8				14·72		
6100	9 51	13 12	4·3	7	1013	11·8				15·03		
6200	10 5	13 33	4·1	7	1008	11·7				15·34		
6300	10 19	13 54	4·0	7	1003	11·6				15·66		
6400	10 33	14 16	3·9	7	999	11·5				15·98		
6500	10 47	14 38	3·8	6	995	11·5				16·31		

Range Table for 12·5-inch R.M.L. Gun. (Mark II.)

Based on Calculation.

Charge, 157½ lbs. Prism.^{2}.
Gravimetric density, $\frac{38\cdot1}{\cdot728}$.
Projectile, 820 lbs., with automatic gas-check.
Muzzle velocity, 1315 f.s.
Jump, 3 minutes.

Range.	Elevation.		Angle of Descent.		Remaining Velocity.	Slope of Descent.	To hit an Object 10 feet high Range must be known within	Time of Flight.	Fuze Scale for 15 sec. M L. Wood Time Fuze. Based on practice, 22.10.84. Range.	Fuze.
yards.	°	'	°	'	f.s.	1 in	yards.	seconds.	yards.	tenths.
0										
100	0	7	0	12	1305	286	477	0·23	250	1·0
200	0	17	0	22	1295	156	260	0·46	335	1·5
300	0	27	0	32	1284	107	179	0·69	420	2·0
400	0	37	0	42	1274	82	136	0·92	500	2·5
500	0	47	0	53	1264	65	108	1·16	585	3·0
600	0	57	1	4	1255	54	90	1·40	665	3·5
700	1	7	1	15	1245	46	76	1·64	745	4·0
800	1	17	1	26	1236	40	67	1·89	825	4·5
900	1	28	1	38	1226	35	59	2·14	900	5·0
1000	1	38	1	50	1217	31	52	2·39	980	5·5
1100	1	49	2	2	1209	28	47	2·64	1055	6·0
1200	2	0	2	14	1200	26	43	2·89	1135	6·5
1300	2	11	2	26	1191	24	39	3·14	1215	7·0
1400	2	22	2	39	1182	22	36	3·39	1290	7·5
1500	2	33	2	52	1173	20	33	3·64	1365	8·0
1600	2	44	3	6	1165	18	31	3·89	1440	8·5
1700	2	55	3	20	1157	17	29	4·15	1515	9·0
1800	3	7	3	34	1149	16	27	4·40	1590	9.5
1900	3	19	3	48	1141	15	25	4·66	1665	10·0
2000	3	31	4	2	1133	14	23	4·92	1740	10·5
2100	3	43	4	17	1126	13	22	5·18	1815	11·0
2200	3	55	4	32	1118	13	21	5·45	1890	11·5
2300	4	7	4	47	1110	12	20	5·72	1965	12·0
2400	4	20	5	2	1103	11	19	6·00	2040	12·5
2500	4	32	5	17	1096	11	18	6·28	2110	13·0
2600	4	45	5	33	1089	10	17	6·56	2185	13·5
2700	4	58	5	49	1082	9·8	16	6·84	2260	14·0
2800	5	11	6	5	1075	9·4	16	7·12	2330	14·5
2900	5	24	6	22	1068	9·0	15	7·40	2405	15·0
3000	5	37	6	39	1062	8·6	14	7·69	2475	15·5
3100	5	51	6	56	1056	8·3	14	7·98	2550	16·0
3200	6	4	7	13	1050	7·9	13	8·26	2620	16·5
3300	6	18	7	31	1044	7·6	13	8·55	2696	17·0
3400	6	32	7	49	1038	7·3	12	8·84	2765	17·5
3500	6	46	8	7	1033	7·0	12	9·13	2835	18·0
3600	7	0	8	25	1028	6·8	11	9·42	2910	18·5
3700	7	14	8	43	1023	6·5	11	9·71	2985	19·0
3800	7	28	9	2	1018	6·3	10	10·0	3060	19·5
3900	7	42	9	21	1013	6·1	10	10·3	3135	20·0
4000	7	57	9	40	1008	5·9	10	10·6	3210	20·5
4100	8	11	9	59	1004	5·7	9	10·9	3285	21·0
4200	8	26	10	18	999	5·5	9	11·2	3360	21·5
4300	8	40	10	37	994	5·3	9	11·5	3435	22·0
4400	8	55	10	56	990	5·2	9	11·8	3510	22·5
4500	9	10	11	16	985	5·0	8	12·1	3585	23·0
4600	9	24	11	36	980	4·9	8	12·45	3660	23·5
4700	9	39	11	56	976	4·7	8	12·75	3730	24·0
4800	9	54	12	16	971	4·6	8	13·1	3805	24·5
4900	10	9	12	37	967	4·5	7	13·4	3875	25·0
5000	10	24	12	58	963	4·3	7	13·7	3950	25·5
									4020	26·0
									4095	26·5
									4170	27·0
									4245	27·5
									4320	28·0
									4390	28·5
									4460	29·0
									4530	29·5
									4600	30·0

Range Table for 12-inch R.M.L. Gun, 35 tons. (Revised 3/85.)
Based on Practice of 22. 12. 79., 13. 2. 80., and 3. 3. 80.

Charge, 140 lbs. P². $\frac{30\cdot0}{\cdot926}$.

Projectile, studless shell, with automatic gas-check or studded Palliser shell, with Mark I. or Mark II. gas-check, weight 714 lbs.

Muzzle velocity, 1390 f.s.

Mounting, wood, garrison. Jump, nil.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an Object 16 feet high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	Fifty per Cent. of Rounds should fall within			Time of Flight.	Fuze Scale for 15 secs. M.L. Wood Time Fuze. Estimated from practice in 12·5 and 11-inch Guns.	
							Length.	Breadth.	Height.			
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	yds.	secs.	yds.	fuze.
0					1390	16·0						
100	0 8	0 8	420	700	1378	15·8		There is not sufficient data to compile accuracy tables, but as far as can be judged the accuracy is similar to that of the 12·5-inch gun with 130 lbs. charge.		0·21	255	1·0
200	0 17	0 17	200	333	1366	15·7				0·43	345	1·5
300	0 25	0 27	127	212	1354	15·5				0·65	430	2·0
400	0 35	0 37	93	155	1342	15·4				0·87	515	2·5
500	0 44	0 47	73	122	1330	15·2				1·10	600	3·0
600	0 53	0 56	61	102	1319	15·1				1·33	685	3·5
700	1 2	1 6	52	87	1308	15·0				1·56	770	4·0
800	1 12	1 16	45	75	1297	14·8				1·79	850	4·5
900	1 21	1 26	40	67	1286	14·7				2·02	930	5·0
1000	1 31	1 37	36	59	1275	14·6				2·26	1010	5·5
1100	1 41	1 49	32	53	1264	14·4				2·50	1090	6·0
1200	1 50	2 1	29	47	1253	14·3				2·74	1170	6·5
1300	2 0	2 13	26	43	1243	14·2				2·98	1250	7·0
1400	2 10	2 24	24	40	1233	14·0				3·22	1330	7·5
1500	2 20	2 36	22	37	1223	13·9				3·47	1410	8·0
1600	2 30	2 48	20	34	1213	13·8				3·72	1490	8·5
1700	2 40	3 0	19	32	1203	13·6				3·97	1570	9·0
1800	2 50	3 12	18	30	1194	13·5				4·22	1645	9·5
1900	3 0	3 24	17	28	1185	13·4				4·47	1720	10·0
2000	3 10	3 36	16	26	1176	13·2				4·72	1800	10·5
2100	3 21	3 49	15	25	1167	13·1				5·07	1875	11·0
2200	3 32	4 2	14	24	1158	13·0				5·23	1950	11·5
2300	3 43	4 15	13	22	1149	12·9				5·49	2025	12·0
2400	3 54	4 28	13	21	1140	12·7				5·75	2100	12·5
2500	4 5	4 42	12	20	1132	12·6				6·01	2175	13·0
2600	4 16	4 56	11	19	1124	12·5				6·27	2250	13·5
2700	4 28	5 11	11	18	1116	12·4				6·53	2325	14·0
2800	4 39	5 26	11	18	1108	12·3				6·79	2400	14·5
2900	4 50	5 41	10	17	1100	12·2				7·06	2475	15·0
3000	5 2	5 57	9·6	16	1092	12·1				7·33	2550	15·5
3100	5 15	6 13	9·2	15	1085	12·0				7·60	2625	16·0
3200	5 25	6 29	8·8	15	1078	11·9				7·87	2700	16·5
3300	5 37	6 46	8·4	14	1071	11·9				8·14	2775	17·0
3400	5 50	7 2	8·1	14	1064	11·8				8·41	2850	17·5
3500	6 3	7 19	7·8	13	1057	11·7				8·69	2925	18·0
3600	6 16	7 36	7·5	12	1051	11·7				8·97	3000	18·5
3700	6 30	7 53	7·2	12	1045	11·6				9·25	3075	19·0
3800	6 43	8 11	7·0	12	1040	11·5				9·53	3150	19·5
3900	6 56	8 29	6·7	11	1035	11·5				9·81	3225	20·0
4000	7 10	8 47	6·5	11	1030	11·4				10·1	3300	20·5
4100	7 24	9 5	6·3	10	1025	11·3				10·4	3375	21·0
4200	7 38	9 24	6·0	10	1020	11·3				10·7	3450	21·5
4300	7 52	9 43	5·8	10	1015	11·2				10·9	3525	22·0
4400	8 6	10 2	5·6	9	1010	11·1				11·2	3600	22·5
4500	8 20	10 21	5·5	9	1005	11·1				11·5	3675	23·0
4600	8 34	10 41	5·3	9	1000	11·0				11·8	3750	23·5
4700	8 48	11 1	5·1	9	995	11·0				12·1	3825	24·0
4800	9 2	11 21	5·0	8	990	10·9				12·4	3900	24·5
4900	9 16	11 41	4·8	8	986	10·9				12·7	3975	25·0
5000	9 31	12 1	4·7	8	982	10·8				13·0	4050	25·5
5100	9 46	12 22	4·6	8	978	10·7				13·3	4125	26·0
5200	10 1	12 43	4·5	7	974	10·7				13·6	4200	26·5
5300	10 16	13 4	4·4	7	970	10·6				13·9	4275	27·0
5400	10 32	13 26	4·3	7	966	10·6				14·3	4350	27·5
5500	10 47	13 48	4·2	7	962	10·5				14·6	4420	28·0
5600	11 3	14 10	4·1	7	958	10·4				14·9	4490	28·5
5700	11 19	14 32	4·0	7	954	10·4				15·2	4560	29·0
5900	11 35	14 55	3·9	6	950	10·3				15·6	4680	29·5
5900	11 51	15 17	3·8	6	946	10·3				15·9	4700	30·0
6000	12 8	15 40	3·7	6	942	10·2				16·2		

Range Table for 12-inch R.M.L. Gun of 35 Tons. (S.S)

Based on Practice of 16. and 17. 12. 85.

Charge, 55 lb. P². Gravimetric density, $\frac{31\cdot8}{0\cdot797}$.

Projectile, common shell, Mark II. gas-check; weight 629 lb.
Muzzle velocity, 1244 f.s.
Carriage, wrought iron, garrison sliding.
Jump (estimated), 4 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	Time of Flight.
yds.	° ′	° ′	f.s.	yds.	yds.	secs.
0						
100	0 10		1233			0·33
200	0 17	0 20	1222	50	0·29	0.47
300	0 28	0 33	1211	49	0·43	0·72
400	0 39	0 46	1200	47	0·58	0·97
500	0 50	0 58	1189	46	0·72	1·22
600	1 1	1 10	1178	45	0·87	1·48
700	1 12	1 22	1168	44	1·01	1·74
800	1 25	1 34	1158	43	1·16	2·
900	1 37	1 48	1148	42	1·31	2·26
1000	1 49	2 2	1138	41	1·45	2·52
1100	2 1	2 16	1129	40·5	1·60	2·78
1200	2 13	2 30	1120	40	1·74	3·05
1300	2 25	2 44	1111	39·5	1·89	3·32
1400	2 37	2 58	1103	39	2·03	3·59
1500	2 49	3 12	1095	39	2·18	3·86
1600	3 1	3 27	1088	38·5	2·32	4·14
1700	3 14	3 42	1081	38	2·47	4·42
1800	3 27	3 57	1074	38	2·61	4·70
1900	3 40	4 12	1067	37·5	2·76	4·98
2000	3 53	4 27	1053	37	2·91	5·26
2100	4 6	4 42	1047	37	3·05	5·54
2200	4 19	4 57	1041	36·5	3·20	5·82
2300	4 32	5 12	1035	36	3·34	6·10
2400	4 45	5 28	1029	36	3·49	6·38
2500	4 59	5 44	1023	35·5	3·63	6·67
2600	5 13	6 0	1017	35·5	3·78	6·96
2700	5 27	6 16	1012	35	3·92	7·25
2800	5 42	6 33	1007	35	4·07	7·54
2900	6 6	6 49	1002	35	4·21	7·83
3000	6 11	7 6	997	35	4·36	8·12
3100	6 26	7 23	992	34·5	4·51	8·42
3200	6 41	7 40	987	34·5	4·65	8·72
3300	6 56	7 58	982	34	4·80	9·03
3400	7 12	8 16	977	34	4·94	9·34
3500	7 28	8 34	972	33·5	5·09	9·66
3600	7 44	8 52	967	33·5	5·23	9·98
3700	8 1	9 10	962	33·5	5·38	10·31
3800	8 17	9 29	957	33	5·52	10·64
3900	8 33	9 48	952	33	5·67	10·98
4000	8 49	10 7	947	32·5	5·81	11·32

Fuze Scale.	
tenths.	yds.
1	215
1·5	295
2	375
2·5	455
3	535
3·5	615
4	695
4·5	775
5	850
5·5	925
6	1000
6·5	1075
7	1150
7·5	1225
8	1300
8·5	1375
9	1450
9·5	1525
10	1600
10·5	1675
11	1750
11·5	1825
12	1900
12·5	1975
13	2050
13·5	2125
14	2200
14·5	2275
15	2350
15·5	2420
16	2490
16·5	2560
17	2630
17·5	2700
18	2770
18·5	2840
19	2910
19·5	2980
20	3050
20·5	3120
21	3190
21·5	3260
22	3330
22·5	3395
23	3460
23·5	3525
24	3590
24·5	3655
25	3720
25·5	3785
26	3850
26·5	3915
27	3980

Range Table for 12-inch R.M.L. Gun of 35 tons.
Based on Practice of 16. 5. 81, and on Calculation.

Charge, 85 lb. P^2.
Projectile, studless shell, with automatic gas-check; weight 714 lb.
Muzzle velocity, 1180 f.s.
Gravimetric density, $\frac{36 \cdot 2}{0 \cdot 766}$.
Jump (estimated at) 5 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 ft. high, range must be known within	Remaining Velocity.	Time of Flight.	Estimated Fuze scale. 15 secs. M.L. Wood Time Fuze.*	
yds.	° ′	° ′	1 in	yds.	f. s.	secs.	yds.	fuze.
0					1180			
100	0 7	0 12	286	477	1171	0·25	150	0·5
200	0 19	0 24	143	238	1162	0·51	225	1·0
							300	1·5
300	9 31	0 37	93	155	1153	0·77	375	2·0
400	0 44	0 51	67	112	1144	0·93	450	2·5
500	0 56	1 4	54	90	1136	1·30	520	3·0
							595	3·5
600	1 9	1 18	44	73	1127	1·56	670	4·0
700	1 22	1 31	38	63	1119	1·83	740	4·5
800	1 34	1 45	33	55	1111	2·09	815	5·0
							890	5·5
900	1 47	2 0	29	48	1103	2·36	965	6·0
1000	2 0	2 14	26	43	1095	2·63	1040	6·5
1100	2 13	2 28	23	39	1088	2·90	1110	7·0
							1185	7·5
1200	2 26	2 42	21	35	1081	3·17	1260	8·0
1300	2 39	2 57	19	32	1074	3·45	1335	8·5
1400	2 52	3 11	18	30	1067	3·73	1405	9·0
							1480	9·5
1500	3 6	3 26	17	28	1061	4·01	1550	10·0
1600	3 20	3 41	16	26	1055	4·29	1620	10·5
1700	3 34	3 57	15	24	1049	4·58	1690	11·0
							1760	11·5
1800	3 48	4 13	14	23	1043	4·87	1830	12·0
1900	4 2	4 29	13	21	1038	5·16	1895	12·5
2000	4 17	4 45	12	20	1033	5·43	1965	13·0
							2030	13·5
2190	4 32	5 2	11	19	1028	5·74	2095	14·0
2200	4 46	5 19	11	18	1023	6·03	2165	14·5
2300	5 1	5 36	10	17	1018	6·32	2240	15·0
							2310	15·5
2400	5 15	5 54	9·7	16	1014	6·62	2380	16·0
2500	5 30	6 12	9·2	15	1009	6·92	2450	16·5
2600	5 45	6 30	8·8	15	1005	7·22	25[illegible]0	17·0
							2590	17·5
2700	6 0	6 48	8·4	14	1000	7·52	2660	18·0
2800	6 16	7 7	8·0	13	9[illegible]6	7·82	2730	18·5
2900	6 31	7 26	7·7	13	991	8·12	2800	19·0
							2865	19·5
3000	6 47	7 45	7·3	12	9	8·42	2935	20·0
3100	7 3	8 4	7·1	12	987	8·73	3005	20·5
3200	7 19	8 23	6·8	11	978	9·04	3070	21·0
							3140	21·5
3300	7 35	8 43	6·5	11	974	9·35	3210	22·0
3400	7 51	9 3	6·3	10	969	9·66	3275	22·5
3500	8 7	9 23	6·1	10	965	9·97	3340	23·0
							3405	23·5
3600	8 23	9 43	5·8	10	961	10·28	3470	24·0
3700	8 39	10 4	5·6	9	957	10·60	3535	24·5
3800	8 55	10 25	5·4	9	953	10·92	3600	25·0
							3665	25·5
3900	9 11	10 46	5·3	9	949	11·24	3730	26·0
4000	9 28	11 7	5·1	8	945	11·56	3795	26·5
							3860	27·0
							3925	27·5
							3990	28·0
							4055	28·5
							4120	29·0
							4185	29·5
							4250	30·0

* Based on practice in 11-inch and 12·5-inch guns with reduced charges.

Range Table for 12-inch R.M.L. Gun of 35 Tons. (L.S.)

Based on Calculation.

Charge, 110 lb. P. Gravimetric density, $\frac{33}{0 \cdot 840}$.
Projectile, studless Palliser; weight 820 lb.
Muzzle velocity, 1340 f.s.
Mounting, iron, garrison.
Jump, 5 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	Time of Flight.
yds.	° ′	° ′	f.s.	yds.	yds.	secs.
0						
100	0 3	0 10	1328	52	0·14	0·23
200	0 12	0 20	1316	50	0·29	0·46
300	0 21	0 30	1305	49	0·43	0·69
400	0 30	0 40	1294	49	0·58	0·92
500	0 40	0 51	1283	48	0·72	1·15
600	0 50	1 2	1272	48	0·87	1·38
700	1 0	1 13	1262	48	1·01	1·61
800	1 10	1 24	1252	47	1·16	1·84
900	1 21	1 36	1242	47	1·31	2·08
1000	1 32	1 48	1232	47	1·45	2·32
1100	1 43	2 0	1222	46	1·60	2·56
1200	1 54	2 12	1212	46	1·74	2·71
1300	2 5	2 24	1202	46	1·89	2·96
1400	2 16	2 36	1193	46	2·03	3·21
1500	2 27	2 48	1184	45	2·18	3·46
1600	2 38	3 0	1175	45	2·32	3·72
1700	2 50	3 12	1166	45	2·47	3·98
1800	3 2	3 25	1157	45	2·61	4·24
1900	3 14	3 38	1148	44	2·76	4·60
2000	3 26	3 51	1139	44	2·91	4·86
2100	3 38	4 4	1131	44	3·05	5·13
2200	3 50	4 18	1123	43	3·20	5·40
2300	4 2	4 33	1115	43	3·34	5·67
2400	4 14	4 48	1107	43	3·49	5·94
2500	4 26	5 3	1099	42	3·63	6·21
2600	4 38	5 18	1091	42	3·78	6·48
2700	4 51	5 33	1083	42	3·92	6·76
2800	5 4	5 48	1076	41	4·07	7·04
2900	5 17	6 3	1069	41	4·21	7·32
3000	5 30	6 19	1062	40	4·36	7·60
3100	5 43	6 35	1056	40	4·51	7·88
3200	5 56	6 51	1050	39	4·65	8·16
3300	6 9	7 8	1045	39	4·80	8·44
3400	6 22	7 25	1040	38	4·94	8·72
3500	6 36	7 42	1035	38	5·09	9·0
3600	6 50	8 0	1030	37	5·23	9·28
3700	7 4	8 18	1025	37	5·38	9·56
3800	7 18	8 36	1020	37	5·52	9·84
3900	7 32	8 54	1015	36	5·67	10·22
4000	7 46	9 13	1010	36	5·81	10·49

Fuze Scale. 15 seconds Wood Time.	
tenths.	yds.
1	240
1·5	325
2	410
2·5	495
3	580
3·5	665
4	750
4·5	835
5	915
5·5	995
6	1075
6·5	1155
7	1235
7·5	1315
8	1390
8·5	1465
9	1540
9·5	1615
10	1690
10·5	1765
11	1840
11·5	1950
12	1980
12·5	2055
13	2130
13·5	2205
14	2280
14·5	2350
15	2420
15·5	2490
16	2560
16·5	2630
17	2700
17·5	2770
18	2840
18·5	2910
19	2980
19·5	3050
20	3120
20·5	3190
21	3260
21·5	3330
22	3100
22·5	3470
23	3540
23·5	3610
24	3675
24·5	3740
25	3805
25·5	3870
26	3935
26·5	4000

Range Table for 12-inch R.M.L. Gun of 25 tons. (Revised 3/85.)

Based on Practice of 17. 12. 78.

Charge, 85 lbs. P².
Projectile, studless shell or studded Palliser shell, with Mark I. or Mark II. gas-check; weight, 615 lbs.
Muzzle velocity, 1292 f.s.
Mounting, iron, garrison.
Jump, 5 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	Fifty per Cent. of Rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Fuze Scale 15 secs. M.L. wood time fuze.	
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	feet	secs.	yds.	tenths
0					1292	13·6						
100	0 5	0 10	333	555	1279	13·4	28	0·04	0·2	0·23	210	1·0
200	0 15	0 21	164	273	1267	13·3	28	0·09	0·5	0·46	305	1·5
300	0 25	0 31	111	185	1255	13·1	28	0·13	0·7	0·70	390	2·0
400	0 36	0 42	82	137	1243	13·0	28	0·18	1·0	0·94	465	2·5
500	0 46	0 53	65	108	1231	12·8	28	0·23	1·3	1·19	550	3·0
600	0 57	1 5	53	88	1220	12·7	28	0·27	1·6	1·44	630	3·5
700	1 8	1 17	45	74	1209	12·5	28	0·32	1·9	1·69	710	4·0
800	1 19	1 28	39	65	1198	12·4	28	0·37	2·1	1·94	790	4·5
900	1 30	1 40	34	57	1187	12·3	28	0·42	2·4	2·20	870	5·0
1000	1 41	1 52	31	51	1176	12·2	28	0·47	2·7	2·46	950	5·5
1100	1 52	2 4	28	46	1165	12·0	28	0·52	3·0	2·72	1030	6·0
1200	2 3	2 17	25	42	1155	11·9	28	0·57	3·4	2·98	1110	6·5
1300	2 14	2 30	23	38	1145	11·8	28	0·63	3·7	3·25	1190	7·0
1400	2 26	2 44	21	35	1135	11·6	28	0·68	4·0	3·52	1270	7·5
1500	2 38	2 58	19	32	1125	11·5	28	0·74	4·4	3·79	1350	8·0
1600	2 50	3 12	18	30	1115	11·4	28	0·80	4·8	4·06	1430	8·5
1700	3 2	3 27	17	28	1106	11·3	28	0·86	5·1	4·34	1506	9·0
1800	3 14	3 42	15	26	1097	11·2	29	0·92	5·5	4·62	1580	9·5
1900	3 26	3 57	14	24	1088	11·1	29	0·98	5·9	4·90	1650	10·0
2000	3 38	4 12	14	23	1079	11·0	29	1·0	6·3	5·18	1720	10·5
2100	3 51	4 28	13	21	1071	10·9	29	1·1	6·7	5·47	1795	11·0
2200	4 4	4 44	12	20	1063	10·8	29	1·2	7·2	5·76	1870	11·5
2300	4 17	5 0	11	19	1056	10·7	30	1·2	7·7	6·05	1955	12·0
2400	4 30	5 16	11	18	1049	10·7	30	1·3	8·2	6·34	2020	12·5
2500	4 43	5 33	10	17	1043	10·6	30	1·4	8·7	6·64	2090	13·0
2600	4 56	5 50	9·8	16	1037	10·5	30	1·5	9·3	6·94	2160	13·5
2700	5 10	6 7	9·3	16	1031	10·4	31	1·5	9·9	7·24	2230	14·0
2800	5 24	6 24	8·9	15	1025	10·3	31	1·6	11	7·54	2300	14·5
2900	5 38	6 42	8·5	14	1019	10·2	31	1·7	11	7·84	2370	15·0
3000	5 52	7 0	8·1	14	1013	10·2	32	1·8	12	8·15	2445	15·5
3100	6 6	7 19	7·8	13	1007	10·1	32	1·9	13	8·46	2515	16·0
3200	6 21	7 38	7·5	12	1002	10·0	32	2·0	13	8·77	2590	16 5
3300	6 36	7 57	7·2	12	997	10·0	33	2·1	14	9·08	2660	17·0
3400	6 51	8 17	6·9	11	992	9·9	33	2·2	15	9·40	2730	17·5
3500	7 6	8 37	6·6	11	987	9·8	34	2·3	15	9·72	2800	18·0
3600	7 21	8 57	6·3	11	981	9·8	34	2·4	16	10·0	2870	18·5
3700	7 36	9 17	6·1	10	976	9·7	35	2·5	17	10·4	2940	19·0
3800	7 51	9 38	5·9	10	971	9·7	35	2·6	18	10·7	3010	19·5
3900	8 6	9 59	5·7	9	966	9·6	36	2·7	19	11·0	3080	20·0
4000	8 22	10 20	5·5	9	961	9·6	37	2·8	20	11·4	3150	20·5
4100	8 38	10 41	5·3	9	956	9·5				11·7	3220	21·0
4200	8 54	11 2	5·1	9	951	9·5				12·0	3290	21·5
4300	9 10	11 23	5·0	8	946	9·4				12·3	3360	22·0
4400	9 26	11 45	4·8	8	941	9·3				12·7	3430	22·5
4500	9 42	12 7	4·6	8	936	9·3				13·0	3500	23·0
4600	9 59	12 29	4·5	8	931	9·2				13·3	3570	23·5
4700	10 16	12 51	4·4	7	927	9·2				13·6	3640	24·0
4800	10 33	13 13	4·3	7	922	9·1				14·0	3710	24·5
4900	10 50	13 36	4·1	7	918	9·1				14·3	3780	25·0
5000	11 7	13 59	4·0	7	914	9·0				14·6	3850	25·5
5100	11 24	14 22	3·9	7	909	9·0				14·9	3920	26·0
5200	11 31	14 45	3·8	6	905	8·9				15·2	3990	26·5
5300	11 58	15 8	3·7	6	901	8·9				15·5	4060	27·0
5400	12 16	15 32	3·6	6	896	8·8				15·9	4130	27·5
5500	12 34	15 56	3·5	6	892	8·8				16·2	4200	28·0
5600	12 52	16 20	3·4	6	888	8·7				16·5	4265	28·5
5700	13 10	16 45	3·3	6	884	8·7				16·9	4330	29·0
5800	13 28	17 10	3·2	5	880	8·6				17·2	4395	29·5
5900	13 46	17 35	3·2	5	876	8·6				17·5	4460	30·0
6000	14 5	18 0	3·1	5	872	8·5				17·9		

Range Table for 12-inch R.M.L. Gun of 25 tons

Based on Calculation.

Charge, 55 lbs. P. Gravimetric density, $\frac{34 \cdot 3}{\cdot 808}$.

Projectile, studded common shell, filled with P. and F.G. powder, with Mark II. gas-check. Total weight, 521 lbs.

Mounting, W.I., garrison.

Jump, 12 minutes.

Muzzle velocity, 1140 f.s.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an Object 10 feet high. Range must be known within	Time of Flight.
yards.	° ′	° ′	f.s.	yards.	seconds.
0			1 in		
100		0 13	286	477	0·26
200	0 13	0 26	132	238	0·53
300	0 26	0 40	86	143	0·70
400	0 40	0 54	64	106	1·07
500	0 54	1 8	51	84	1·35
600	1 7	1 23	41	69	1·63
700	1 21	1 38	35	58	1·91
800	1 35	1 53	30	51	2·19
900	1 49	2 9	27	44	2·48
1000	2 4	2 25	24	39	2·77
1100	2 19	2 41	21	36	3·06
1200	2 34	2 57	19	33	3·35
1300	2 49	3 14	18	30	3·64
1400	3 4	3 31	16	27	3·93
1500	3 19	3 48	15	25	4·23
1600	3 34	4 5	14	23	4·53
1700	3 49	4 23	13	22	4·83
1800	4 5	4 41	12	20	5·13
1900	4 21	4 59	11	19	5·43
2000	4 37	5 18	11	18	5·74
2100	4 53	5 37	10	17	6·05
2200	5 9	5 56	9·6	16	6·36
2300	5 25	6 16	9·1	15	6·67
2400	5 42	6 36	8·6	14	6·98
2500	5 59	6 56	8·2	14	7·30
2600	6 16	7 17	7·8	13	7·62
2700	6 33	7 38	7·5	12	7·94
2800	6 50	7 59	7·1	12	8·26
2900	7 7	8 20	6·8	11	8·58
3000	7 24	8 42	6·5	11	8·90
3100	7 41	9 4	6·3	10	9·23
3200	7 59	9 26	6·0	10	9·56
3300	8 17	9 49	5·8	10	9·89
3400	8 35	10 12	5·6	9	10·22
3500	8 53	10 35	5·4	9	10·55
3600	9 11	10 58	5·2	9	10·88
3700	9 29	11 22	5·0	8	11·22
3800	9 47	11 46	4·8	8	11·56
3900	10 5	12 11	4·6	8	11·90
4000	10 24	12 26	4·5	7	12·24

Fuze Scale for 15 sec. M.L. Wood Time Fuze.	
yards.	tenths.
240	1·0
315	1·5
390	2·0
465	2·5
540	3·0
610	3·5
680	4·0
750	4·5
825	5·0
900	5·5
975	6·0
1050	6·5
1120	7·0
1190	7·5
1260	8·0
1330	8·5
1400	9·0
1470	9·5
1540	10·0
1610	10·5
1680	11·0
1750	11·5
1820	12·0
1890	12·5
1960	13·0
2030	13·5
2100	14·0
2170	14·5
2240	15·0
2310	15·5
2380	16·0
2445	16·5
2510	17·0
2575	17·5
2640	18·0
2705	18·5
2770	19·0
2835	19·5
2900	20·0
2965	20·5
3030	21·0
3095	21·5
3160	22·0
3225	22·5
3290	23·0
3355	23·5
3420	24·0
3485	24·5
3550	25·0
3615	25·5
3680	26·0
3745	26·5
3810	27·0
3875	27·5
3940	28·0
4000	28·5
4060	29·0
4120	29·5
4180	30·0

RANGE TABLE FOR 11-INCH R.M.L. GUN. (Revised 3/85.)

Based on Practice of 17. 2. 75, 1. 3. 75, 6. 6. 77, 31. 12. 78, and 2. 1. 79, and on Calculation.

Charge, 85 lbs. P.
Projectile, studded or studless shell, with Mark I., Mark II., or automatic gas-check; weight, 546 lbs.
Muzzle velocity, 1360 f.s.
Mounting, iron, garrison.
Jump, 3 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Five Minutes elevation increases or decreases the Range by	Fifty per Cent. of Rounds should fall within*			Time of Flight.	Fuze Scale with 15 secs. M.L. wood time fuze.	
							Length.	Breadth.	Height.			
yds.	° ′	° ′	1 in	yds.	f.s.	yds.	yds.	yds.	feet	secs.	yds.	tenths
0					1360	14·2						
100	0 6	0 9	369	615	1347	14·1	25	0·04	0·2	0·22	250	1·0
200	0 15	0 18	184	307	1334	13·9	25	0·09	0·4	0·44	335	1·5
300	0 24	0 28	123	205	1321	13·8	25	0·13	0·6	0·66	420	2·0
400	0 33	0 38	90	151	1309	13·6	25	0·18	0·9	0·89	495	2·5
500	0 43	0 48	72	119	1297	13·5	25	0·22	1·1	1·12	580	3·0
600	0 53	0 59	58	97	1285	13·3	25	0·27	1·3	1·35	660	3·5
700	1 3	1 10	49	82	1273	13·2	25	0·32	1·6	1·59	740	4·0
800	1 13	1 21	42	71	1262	13·0	25	0·36	1·8	1·83	820	4·5
900	1 23	1 32	37	62	1251	12·9	25	0·41	2·1	2·07	900	5·0
1000	1 33	1 43	33	56	1240	12·8	25	0·46	2·3	2·31	980	5·5
1100	1 44	1 55	30	50	1229	12·7	25	0·51	2·6	2·55	1060	6·0
1200	1 54	2 7	27	45	1218	12·5	26	0·56	2·9	2·80	1140	6·5
1300	2 5	2 19	25	41	1207	12·4	26	0·61	3·1	3·05	1220	7·0
1400	2 15	2 31	23	38	1196	12·3	26	0·67	3·4	3·30	1300	7·5
1500	2 26	2 44	21	35	1186	12·1	26	0·72	3·7	3·55	1380	8·0
1600	2 37	2 57	19	32	1176	12·0	26	0·78	4·0	3·80	1460	8·5
1700	2 48	3 10	18	30	1166	11·9	26	0·83	4·3	4·06	1535	9·0
1800	2 59	3 23	17	28	1156	11·8	27	0·89	4·7	4·32	1610	9·5
1900	3 10	3 37	16	26	1147	11·7	27	0·94	5·0	4·58	1680	10·0
2000	3 21	3 51	15	25	1138	11·6	27	1·0	5·4	4·84	1755	10·5
2100	3 32	4 5	14	23	1129	11·5	27	1·1	5·9	5·10	1830	11·0
2200	3 44	4 20	13	22	1120	11·4	27	1·1	6·3	5·36	1905	11·5
2300	3 56	4 35	12	21	1111	11·3	27	1·2	6·7	5·63	1980	12·0
2400	4 8	4 50	12	20	1102	11·2	28	1·3	7·1	5·90	2055	12·5
2500	4 20	5 5	11	19	1094	11·1	28	1·3	7·5	6·17	2125	13·0
2600	4 32	5 21	11	18	1086	11·0	28	1·4	8·0	6·44	2195	13·5
2700	4 44	5 37	10	17	1078	10·9	28	1·5	8·4	6·71	2265	14·0
2800	4 57	5 53	9·7	16	1071	10·9	29	1·5	8·9	6·98	2340	14·5
2900	5 10	6 10	9·3	15	1064	10·8	29	1·6	9·5	7·26	2410	15·0
3000	5 23	6 27	8·9	15	1057	10·7	30	1·7	10	7·54	2485	15·5
3100	5 36	6 44	8·5	14	1051	10·6	30	1·7	11	7·82	2555	16·0
3200	5 49	7 1	8·1	14	1045	10·5	30	1·8	11	8·10	2630	16·5
3300	6 2	7 19	7·8	13	1039	10·5	31	1·9	12	8·39	2700	17·0
3400	6 15	7 37	7·5	12	1033	10·4	31	2·0	13	8·68	2770	17·5
3500	6 28	7 55	7·2	12	1027	10·3	32	2·1	13	8·97	2840	18·0
3600	6 42	8 13	6·9	12	1021	10·2	32	2·2	14	9·26	2910	18·5
3700	6 56	8 32	6·7	11	1016	10·2	33	2·3	15	9·56	2980	19·0
3800	7 10	8 51	6·4	11	1011	10·1	33	2·4	15	9·86	3050	19·5
3900	7 24	9 10	6·2	10	1006	10·1	34	2·5	16	10·2	3120	20·0
4000	7 38	9 29	6·0	10	1001	10·0	34	2·6	17	10·5	3190	20·5
4100	7 52	9 49	5·8	10	996	9·9				10·8	3260	21·0
4200	8 7	10 9	5·6	9	991	9·9				11·1	3330	21·5
4300	8 22	10 29	5·4	9	986	9·8				11·4	3400	22·0
4400	8 37	10 50	5·2	9	981	9·8				11·7	3470	22·5
4500	8 52	11 11	5·1	8	977	9·7				12·0	3540	23·0
4600	9 7	11 32	4·9	8	972	9·7				12·3	3610	23·5
4700	9 22	11 53	4·8	8	967	9·6				12·6	3680	24·0
4800	9 38	12 14	4·6	8	963	9·6				13·0	3750	24·5
4900	9 54	12 36	4·5	7	958	9·5				13·3	3820	25·0
5000	10 10	12 58	4·3	7	954	9·5				13·6	3890	25·5
5100	10 26	13 20	4·2	7	949	9·4				13·9	3960	26·0
5200	10 42	13 42	4·1	7	945	9·4				14·3	4030	26·5
5300	10 58	14 5	4·0	7	940	9·3				14·6	4100	27·0
5400	11 14	14 28	3·9	6	936	9·3				14·9	4170	27·5
5500	11 31	14 51	3·8	6	932	9·3				15·3	4235	28·0
5600	11 48	15 15	3·7	6	928	9·2				15·6	4305	28·5
5700	12 5	15 39	3·6	6	923	9·2				15·9	4370	29·0
5800	12 22	16 3	3·5	6	919	9·1				16·3	4440	29·5
5900	12 39	16 28	3·4	6	915	9·1				16·6	4505	30·0
6000	12 56	16 53	3·3	5	911	9·0				16·9		

* The accuracy would probably be as good as that of the 10-inch R.M.L. with 70 lb. P. with the latest pattern projectiles.

RANGE TABLE FOR 11-INCH R.M.L. GUN.

Based on Calculation.

Charge, 60 lbs. P. Gravimetric density, $\frac{38 \cdot 3}{0 \cdot 724}$.
Projectile, Palliser or common shell (Mark II.) gas-check); weight 547 lbs.
Muzzle velocity, 1115 f.s. Jump, nil.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an Object 10 feet high, Range should be known within	Time of Flight.
yards.	° ′	° ′	f.s.	1 in	yards.	seconds.
0						
100	0 13	0 14	1106	245	409	
200	0 26	0 28	1098	123	204	0·48
300	0 40	0 42	1090	82	136	0·76
400	0 54	0 57	1082	60	101	1·04
500	1 8	1 11	1075	48	81	1·32
600	1 22	1 26	1068	40	67	1·61
700	1 36	1 40	1061	34	57	1·90
800	1 50	1 55	1054	30	50	2·19
900	2 4	2 10	1047	26	44	2·48
1000	2 19	2 25	1040	24	39	2·78
1100	2 34	2 49	1036	21	35	3·08
1200	2 49	2 57	1030	19	32	3·38
1300	3 4	3 13	1024	18	30	3·68
1400	3 19	3 30	1018	16	27	3·98
1500	3 34	3 47	1013	15	25	4·28
1600	3 50	4 4	1008	14	23	4·58
1700	4 6	4 21	1003	13	22	4·88
1800	4 22	4 39	998	12	20	5·18
1900	4 38	4 57	993	12	19	5·48
2000	4 54	5 15	988	11	18	5·78
2100	5 10	5 43	983	10	17	6·09
2200	5 26	5 52	978	9·7	16	6·40
2300	5 42	6 11	973	9·2	15	7·71
2400	5 58	6 31	968	8·8	15	7·02
2500	6 14	6 51	963	8·3	14	7·33
2600	5 30	7 11	958	7·9	13	7·65
2700	6 46	7 31	953	7·6	13	7·97
2800	7 3	7 51	949	7·3	12	8·29
2000	7 20	8 12	945	6·9	12	8·61
3000	7 37	8 33	941	6·7	11	8·93
3100	7 54	8 54	936	6·4	11	9·25
3200	8 11	9 15	931	6·1	10	9·57
3300	8 28	9 36	927	5·9	10	9·89
3400	8 46	9 57	923	5·7	10	10·21
3500	9 4	10 19	919	5·5	9	10·53
3600	9 22	10 40	915	5·3	9	10·86
3700	9 41	11 2	911	5·1	9	11·19
3800	10 0	11 24	907	4·9	8	11·52
3900	10 20	11 47	903	4·8	8	11·85
4000	10 40	12 10	899	4·6	8	12·20

Fuze Scale for 15 Seconds M.L. Wood Time Fuze.	
yards.	tenths.
240	1·0
220	1·5
390	2·0
455	2·5
520	3·0
585	3·5
650	4·0
720	4·5
790	5·0
865	5·5
940	6·0
1010	6·5
1080	7·0
1155	7·5
1220	8·0
1290	8·5
1360	9·0
1430	9·5
1500	10·0
1570	10·5
1640	11·0
1710	11·5
1780	12.0
1850	12·5
1920	13·0
1990	13·5
2060	14·0
2130	14·5
2200	15·0
2270	15·5
2335	16·0
2405	16·5
2470	17·0
2535	17·5
2600	18·0
2665	18·5
2730	19·0
2795	19·5
2860	20·0
2925	20·5
2990	21·0
3050	21·5
3120	22·0
3185	22·5
3250	23·0
3315	23·5
3375	24·0
3440	24·5
3500	25·0
3565	25·5
3625	26·0
3690	26·5
3750	27·0
3815	27·5
3875	28·0
3940	28·5
4000	29·0
4060	29·5
4120	30·0

Range Table for 10-inch R.M.L. Gun.

Based on Calculation and a Practice of 11. 4. 81.

Charge, 70 lbs. P. Gravimetric density, $\frac{29\cdot6}{0\cdot987}$.
Projectile, Palliser shell with gas-check, Mark II., 410 lbs.
Muzzle velocity, 1379 f.s.
Jump, 5 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	Fifty per Cent. of Rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Fuze Scale. Fifteen Seconds. Wood M.L. based on Practice of various dates. (Proof of Fuzes.)	
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	yds.	secs.	dys.	dys.
0					1379	13·2						
100	0 3	0 9	382	636	1365	13·0		The accuracy may be taken as about equal to that of the 9-inch R.M.L. gun with 50 lbs. charge.		0·22		
200	0 12	0 18	191	318	1351	12·9				0·44	245	1·0
300	0 21	0 27	127	212	1337	12·7				0·66	330	1·5
400	0 30	0 37	93	156	1323	12·6				0·89	415	2·0
500	0 39	0 47	73	122	1310	12·4				1·12	500	2·5
600	0 48	0 57	60	101	1297	12·3				1·35	585	3·0
700	0 58	1 8	51	84	1284	12·1				1·58	670	3·5
800	1 8	1 19	44	73	1271	11·0				1·82	755	4·0
900	1 18	1 30	38	64	1258	11·8				2·06	840	4·5
1000	1 28	1 42	34	56	1244	11·7				3·30	920	5·0
1100	1 38	1 54	30	50	1231	11·6				2·54	1005	5·5
1200	1 48	2 6	27	45	1219	11·5				2·78	1085	6·0
1300	1 58	2 18	25	41	1207	11·3				3·03	1170	6·5
1400	2 9	2 31	23	38	1195	11·2				3·28	1250	7·0
1500	2 20	2 44	21	35	1186	11·1				3·53	1335	7·5
1600	2 31	2 57	19	32	1175	11·0				3·78	1415	8·0
1700	2 42	3 10	18	30	1164	10·8				4·04	1500	8·5
1800	2 53	3 24	17	28	1153	10·7				4·30	1580	9·0
1900	3 4	3 38	16	26	1142	10·6				4·56	1665	9·5
2000	3 15	3 52	15	25	1132	10·5				4·82	1745	10·0
2100	3 27	4 7	14	24	1122	10·4				5·09	1830	10.5
2200	3 39	4 22	13	22	1113	10·3				5·36	1910	11·0
2300	3 51	4 37	12	21	1104	10·2				5·63	1090	11·5
2400	4 3	4 52	12	20	1095	10·1				5·90	2070	12·0
2500	4 15	5 8	11	19	1087	10·0				6·18	2150	12·5
2600	4 27	5 24	11	18	1079	9·9				6·46	2225	13·0
2700	4 40	5 42	10	17	1070	9·9				6·74	2300	13·5
2800	4 53	5 58	9·6	16	1061	9·8				7·02	2370	14·0
2900	5 6	6 14	9·2	15	1053	9·7				7·30	2440	14·5
3000	5 19	6 31	8·8	15	1045	9·6				7·59	2510	15·0
3100	5 32	6 48	8·4	14	1038	9·6				7·88	2580	15·5
3200	5 45	7 5	8·0	13	1031	9·5				8·17	2650	16·0
3300	5 59	7 22	7·7	13	1024	9·4				8·46	2720	16·5
3400	6 13	7 40	7·4	12	1018	9·3				8·75	2790	17·0
3500	6 27	7 58	7·1	12	1013	9·3				9·04	2860	17·5
3600	6 41	8 16	6·9	11	1008	9·2				9·34	2935	18·0
3700	6 55	8 34	6·6	11	1003	9·2				9·64	3005	18·5
3800	7 9	8 53	6·4	11	998	9·1				9·94	3075	19·0
3900	7 24	9 12	6·2	10	993	9·1				10·24	3150	19·5
4000	7 39	9 31	6·0	10	988	9·0				10·54	3220	20·0
4100	7 54	9 51	5.8	10	982	9·0				10·84	3290	20·5
4200	8 9	10 11	5·6	9	976	8·9				11·14	3360	21·0
4300	8 24	10 32	5·4	9	970	8·9				11·45	3430	21·5
4400	8 40	10 53	5·2	9	965	8·8				11·76	3500	22·0
4500	8 56	11 14	5·0	8	960	8·8				12·07	3570	22·5
4600	9 12	11 36	4·9	8	956	8·7				12·4	3635	23·0
4700	9 28	11 58	4·7	8	951	8·7				12·7	3705	23·5
4800	9 44	12 21	4·6	8	946	8·6				13·0	3770	24·0
4900	10 0	12 44	4·4	7	942	8·6				13·3	3840	24·5
5000	10 17	13 8	4·3	7	937	8·5				13·7	3905	25·0
5100	10 34	13 32	4·2	7	933	8·5				14·0	3970	25·5
5200	10 51	13 56	4·0	7	928	8·4				14·3	4035	26·0
5300	11 8	14 21	3·9	7	924	8·4				14·7	4105	26·5
5400	11 26	14 46	3·8	6	920	8·3				15·0	4170	27·0
5500	11 43	15 12	3·7	6	915	8·3				15·3	4235	27·5
5600	12 0	15 39	3·6	6	910	8·2				15·6	4300	28·0
5700	12 18	16 7	3·5	6	905	8·2				16·0	4370	28·5
5800	12 36	16 35	3·4	6	900	8·1				16·3	4435	29·0
5900	12 54	17 4	3·3	5	895	8·1				16·6	4500	29·5
6000	13 12	17 33	3·2	5	890	8·0				17·0	4565	30·0

Range Table for 10-inch R.M.L. Gun.

Based on Calculation.

Charge, 44 lbs. P. gravimetric density, $\frac{47 \cdot 1.}{\cdot 589}$

Projectile, common shell with gas-check Mark II.; weight, 410 lb.
Muzzle velocity, 1028 f.s.
Jump, 3 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Time of Flight.	Fuze Scale, 15 secs. M.L. Wood Time Fuze.	
yds.	°	° ′	f.s.	1 in	yds.	secs.	yds.	tenths.
0							240	1·0
100	0 13	0 16	1022	215	355	0·29	320	1·5
200	0 29	0 32	1016	107	179	0·58	390	2·0
300	0 45	0 49	1010	70	117	0·88	455	2·5
400	1 1	1 6	1004	52	87	1·18	520	3·0
500	1 17	1 22	998	42	70	1·48	585	3·5
600	1 33	1 39	993	35	58	1·77	650	4·0
700	1 49	1 56	988	30	49	2·08	720	4·5
800	2 6	2 14	983	26	43	2·39	790	5·0
900	2 23	2 32	978	23	38	2·70	855	5·5
							920	6·0
1000	2 40	2 50	973	20	33	3·01	985	6·5
1100	2 57	3 8	968	18	30	3·32	1050	7·0
1200	3 14	3 26	963	17	28	3·63	1115	7·5
1300	3 31	3 45	958	15	25	3·95	1180	8·0
1400	3 48	4 4	953	14	23	4·27	1250	8·5
1500	4 6	4 23	948	13	22	4·59	1315	9·0
1600	4 24	4 42	943	12	20	4·91	1385	9·5
1700	4 42	5 2	938	11	19	5·23	1450	10·0
1800	5 0	5 22	933	11	18	5·56	1575	10·5
1900	5 18	5 42	928	10	17	5·89	1580	11·0
							1645	11·5
2000	5 36	6 2	923	9·5	16	6·22	1710	12·0
2100	5 54	6 23	918	8·9	15	6·55	1775	12·5
2200	6 12	6 44	913	8·5	14	6·88	1840	13·0
2300	6 31	7 5	908	8·0	13	7·22	1905	13·5
2400	6 50	7 27	903	7·6	13	7·56	1970	14·0
2500	7 9	7 49	898	7·3	12	7·90	2035	14·5
2600	7 28	8 11	894	7·0	12	8·24	2100	15·0
2700	7 47	8 34	890	6·7	11	8·58	2165	15·5
2800	8 6	8 57	886	6·4	11	8·93	2225	16·0
2900	8 25	9 20	882	6·1	10	9·28	2290	16·5
							2355	17·0
3000	8 45	9 44	878	5·8	10	9·63	2420	17·5
3100	9 5	10 8	874	5·6	9	10·0	2480	18·0
3200	9 25	10 32	870	5·4	9	10·3	2545	18·5
3300	9 45	10 57	866	5·2	9	10·7	2605	19·0
3400	10 5	11 22	862	5·0	8	11·1	2670	19·5
3500	10 25	11 47	858	4·8	8	11·4	2730	20·0
3600	10 46	12 13	854	4·6	8	11·8	2795	20·5
3700	11 7	12 39	850	4·4	7	12·2	2855	21·0
3800	11 28	13 5	846	4·3	7	12·5	2920	21·5
3900	11 49	13 33	842	4·1	7	12·9	2980	22·0
4000	12 10	14 1	838	4·0	7	13·2	3040	22·5
							3100	23·0
							3165	23·5
							3225	24·0
							3290	24·5
							3355	25·0
							3420	25·5
							3480	26·0
							3545	26·5
							3605	27·0
							3670	27·5
							3730	28·0
							3795	28·5
							3850	29·0
							3910	29·5
							3970	30·0

Range Table for 9-inch R.M.L. Gun. (Revised 4/85.)

Based on Practice of 15. 1. 79., 29. 5. 79., 1. 9. 81., 19. 5. 82., 4. 7. 82.

Charge, 50 lbs. P.
Projectile, with Mark II. gas-check. Weight 257 lbs.
Mounting, iron, garrison. Jump, 9 minutes.
Muzzle velocity, 1440 f.s.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	Time of Flight.	Fifty per Cent. of rounds should fall within			Fuze Scale. 13 Secs. Wood Time Fuze, with Detonator, Mark III.	
								Length.	Breadth.	Height.		
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	secs.	yds.	yds.	feet.	yds.	tenths.
100		0 8	430	717	1421	11·3	0·21	20	0·04	0·2	250	1·0
200	0 8	0 16	212	353	1402	11·1	0·42	20	0·09	0·3	340	1·5
300	0 16	0 25	138	230	1384	11·0	0·64	20	0·13	0·5	430	2·0
400	0 24	0 34	101	168	1366	10·8	0·86	20	0·18	0·6	520	2·5
500	0 33	0 44	78	130	1348	10·7	1·08	20	0·22	0·8	610	3·0
600	0 42	0 54	64	106	1331	10·5	1·31	20	0·27	1·0	695	3·5
700	0 51	1 4	54	90	1314	10·4	1·54	20	0·32	1·1	780	4·0
800	1 0	1 14	46	77	1297	10·2	1·77	20	0·36	1·3	865	4·5
900	1 9	1 24	41	68	1280	10·1	2·00	20	0·41	1·5	945	5·0
1000	1 18	1 35	36	60	1264	9·9	2·24	20	0·46	1·7	1030	5·5
1100	1 28	1 46	32	54	1248	9·8	2·48	20	0·51	1·9	1115	6·0
1200	1 38	1 57	29	49	1233	9·6	2·72	21	0·56	2·1	1200	6·5
1300	1 48	2 9	27	44	1218	9·5	2·97	21	0·61	2·3	1280	7·0
1400	1 58	2 22	24	40	1204	9·4	3·21	21	0·67	2·6	1365	7·5
1500	2 8	2 34	22	37	1190	9·2	3·46	21	0·72	2·9	1445	8·0
1600	2 19	2 47	21	34	1176	9·1	3·71	22	0·78	3·2	1530	8·5
1700	2 30	3 1	19	32	1162	9·0	3·97	22	0·83	3·5	1610	9·0
1800	2 41	3 15	18	29	1149	8·8	4·23	22	0·89	3·8	1690	9·5
1900	2 52	3 30	16	27	1136	8·7	4·49	22	0·94	4·1	1770	10·0
2000	3 3	3 45	15	25	1124	8·6	4·76	23	1·0	4·5	1850	10·5
2100	3 14	4 1	14	24	1111	8·5	5·03	23	1·1	4·8	1925	11·0
2200	3 26	4 17	13	22	1099	8·4	5·31	23	1·1	5·2	2005	11·5
2300	3 38	4 33	13	21	1088	8·3	5·59	23	1·2	5·6	2080	12·0
2400	3 50	4 50	12	20	1077	8·2	5·88	24	1·3	6·0	2155	12·5
2500	4 2	5 7	11	19	1067	8·1	6·17	24	1·3	6·5	2230	13·0
2600	4 14	5 24	11	18	1058	8·0	6·46	24	1·4	6·9	2300	13·5
2700	4 26	5 41	10	17	1049	8·0	6·76	25	1·5	7·4	2370	14·0
2800	4 38	5 59	9·6	16	1040	7·9	7·06	25	1·5	7·9	2440	14·5
2900	4 51	6 17	9·1	15	1032	7·8	7·37	25	1·6	8·4	2510	15·0
3000	5 4	6 35	8·7	14	1024	7·7	7·67	26	1·7	9·0	2580	15·5
3100	5 17	6 54	8·3	14	1017	7·7	7·98	26	1·7	9·6	2650	16·0
3200	5 30	7 13	7·9	13	1010	7·6	8·28	26	1·8	10	2720	16·5
3300	5 44	7 32	7·5	13	1004	7·5	8·59	27	1·9	11	2790	17·0
3400	5 58	7 51	7·2	12	997	7·5	8·90	27	2·0	11	2860	17·5
3500	6 12	8 10	6·9	12	991	7·4	9·21	27	2·1	12	2930	18·0
3600	6 26	8 29	6·7	11	985	7·4	9·52	28	2·2	13	3000	18·5
3700	6 41	8 49	6·4	11	978	7·3	9·83	28	2·3	13	3070	19·0
3800	6 56	9 9	6·2	10	972	7·3	10·1	28	2·4	14	3140	19·5
3900	7 11	9 29	6·0	10	966	7·2	10·4	28	2·5	15	3210	20·0
4000	7 26	9 50	5·8	10	960	7·2	10·7	29	2·6	16	3280	20·5
4100	7 41	10 11	5·6	9	954	7·1	11·1				3350	21·0
4200	7 56	10 33	5·4	9	948	7·1	11·4				3420	21·5
4300	8 12	10 55	5·2	9	942	7·0	11·7				3485	22·0
4400	8 28	11 17	5·0	8	936	7·0	12·1				3550	22·5
4500	8 44	11 40	4·8	8	930	6·9	12·4				3615	23·0
4600	9 0	12 3	4·7	8	924	6·9	12·7				3680	23·5
4700	9 16	12 27	4·5	8	918	6·8	13·0				3745	24·0
4800	9 33	12 51	4·4	7	912	6·8	13·4				3810	24·5
4900	9 50	13 16	4·2	7	906	6·7	13·7				3875	25·0
5000	10 7	13 41	4·1	7	900	6·7	14·0				3940	25·5
5100	10 24	14 7	4·0	7	895	6·6	14·4				4000	26·0
5200	10 41	14 34	3·8	6	890	6·6	14·7				4065	26·5
5300	10 59	15 1	3·7	6	885	6·6	15·0				4125	27·0
5400	11 17	15 29	3·6	6	880	6·5	15·4				4190	27·5
5500	11 35	15 58	3·5	6	875	6·5	15·7				4245	28·0
5600	11 53	16 28	3·4	6	870	6·4	16·1				4310	28·5
5700	12 11	16 59	3·3	5	865	6·4	16·4				4370	29·0
5800	12 29	17 31	3·2	5	860	6·3	16·7				4435	29·5
5900	12 48	18 4	3·1	5	855	6·3	17·2				4500	30·0
6000	13 7	18 37	3·0	5	850	6·3	17·5					

Range Table for 9-inch R.M.L. Gun.

Based on Practice 1. 9. 81 and on Calculation.

Charge, 33 lbs. P.

Gravimetric density, $\frac{36 \cdot 5}{0 \cdot 760}$.

Projectile, with Mark II. or automatic gas-check.
Weight, 256 lbs.
Jump, 9 minutes.
Muzzle velocity, 1150 f.s.
Mounting, iron, garrison.

Range.	Elevation.		Angle of Descent.		Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Time of Flight.
yds.	°	′	°	′	1 in	yds.	f.s.	secs.
0							1150	
100	0	4	0	13	264	440	1137	0·26
200	0	17	0	27	127	212	1125	0·53
300	0	30	0	41	84	140	1113	0·80
400	0	43	0	55	62	104	1102	1·08
500	0	57	1	9	50	83	1092	1·36
600	1	11	1	24	41	69	1082	1·64
700	1	25	1	39	35	58	1073	1·92
800	1	39	1	54	30	50	1064	2·21
900	1	53	2	10	26	44	1055	2·50
1000	2	7	2	26	24	39	1046	2·79
1100	2	21	2	42	21	35	1037	3·09
1200	2	36	2	59	19	32	1028	3·39
1300	2	51	3	16	18	29	1019	3·69
1400	3	6	3	33	16	27	1012	3·99
1500	3	21	3	50	15	25	1005	4·29
1600	3	36	4	8	14	23	998	4·59
1700	3	51	4	26	13	21	991	4·90
1800	4	7	4	44	12	20	984	5·21
1900	4	23	5	3	11	19	977	5·52
2000	4	39	5	22	11	18	970	5·83
2100	4	55	5	41	10	17	964	6·14
2200	5	11	6	1	9·5	16	958	6·45
2300	5	28	6	21	9·0	15	952	6·76
2400	5	45	6	42	8·5	14	946	7·07
2500	6	2	7	3	8·1	13	940	7·39
2600	6	19	7	24	7·7	13	934	7·71
2700	6	36	7	46	7·3	12	928	8·03
2800	6	54	8	8	7·0	12	922	8·35
2900	7	12	8	31	6·7	11	916	8·68
3000	7	30	8	54	6·4	11	911	9·01
3100	7	48	9	17	6·1	10	905	9·34
3200	8	6	9	41	5·9	10	900	9·67
3300	8	24	10	5	5·6	9	894	10·0
3400	8	43	10	29	5·4	9	889	10·30
3500	9	2	10	54	5·2	9	884	10·70
3600	9	21	11	19	5·0	8	878	11·0
3700	9	40	11	44	4·8	8	873	11·30
3800	10	0	12	10	4·6	8	868	11·70
3900	10	20	12	36	4·5	7	863	12·0
4000	10	40	13	2	4·3	7	858	12·40

Fuze Scale. 15 secs. Wood Time with Detonator Mark III.	
yds.	fuze.
240	1·0
320	1·5
390	2·0
465	2·5
535	3·0
610	3·5
680	4·0
755	4·5
825	5·0
900	5·5
970	6·0
1045	6·5
1115	7·0
1185	7·5
1255	8·0
1330	8·5
1400	9·0
1470	9·5
1540	10·0
1615	10·5
1685	11·0
1755	11·5
1830	12·0
1900	12·5
1970	13·0
2040	13·5
2110	14·0
2180	14·5
2250	15·0
2320	15·5
2395	16·0
2465	16·5
2540	17·0
2610	17·5
2680	18·0
2750	18·5
2820	19·0
2890	19·5
2960	20·0
3030	20·5
3100	21·0
3170	21·5
3235	22·0
3305	22·5
3370	23·0
3435	23·5
3505	24·0
3570	24·5
3640	25·0
3705	25·5
3770	26·0
3835	26·5
3900	27·0
3965	27·5
4030	28·0
4095	28·5
4160	29·0
4235	29·5
4300	30·0

Range Table for 8-inch R.M.L. Gun.

Based on Practice of 1. 11. 70.

Charge, 35 lb. P.
Projectile, weight 180 lbs.
Gravimetric density, $\frac{28\cdot 0}{0\cdot 990}$ (about).*

Muzzle velocity, 1384 f.s.
Mounting, wood, garrison.
Jump, 5 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 ft. high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	50 per cent. of Rounds should fall within: Length.	Breadth.	Height.	Time of Flight.
yards.	° ′	° ′	1 in	yards.	f. s.	ins.	yards.	yards.	feet.	secs.
0					1384	9·7				
100	0 4	0 9	382	636	1362	9·5				0·22
200	0 13	0 18	191	318	1342	9·3				0·44
300	0 22	0 28	123	205	1321	9·2				0·67
400	0 31	0 38	90	151	1300	9·0				0·90
500	0 40	0 49	70	117	1280	8·9				1·14
600	0 49	0 59	58	94	1261	8·7				1·39
700	0 59	1 9	50	83	1242	8·6				1·64
800	1 9	1 20	43	72	1224	8·5				1·89
900	1 20	1 33	37	62	1207	8·3				2·14
1000	1 30	1 44	33	55	1191	8·2				2·39
1100	1 41	1 57	29	49	1175	8·1				2·64
1200	1 52	2 10	26	44	1160	7·9				2·90
1300	2 3	2 23	24	40	1146	7·8				3·16
1400	2 14	2 37	22	36	1132	7·7				3·43
1500	2 26	2 51	20	33	1118	7·6				3·70
1600	2 37	3 5	19	31	1106	7·5				3·97
1700	2 49	3 20	17	29	1093	7·4				4·24
1800	3 1	3 36	16	27	1081	7·3				4·51
1900	3 14	3 52	15	25	1070	7·2				4·79
2000	3 27	4 8	14	23	1059	7·1				5·07
2100	3 40	4 25	13	22	1049	7·0				5·36
2200	3 54	4 42	12	20	1039	6·9				5·65
2300	4 8	5 0	11	19	1029	6·9				5·94
2400	4 22	5 18	11	18	1020	6·8				6·24
2500	4 36	5 37	10	17	1011	6·7				6·54
2600	4 50	5 56	9·6	16	1002	6·7				6·85
2700	5 5	6 16	9·1	15	993	6·6				7·16
2800	5 20	6 36	8·6	14	985	6·5				7·47
2900	5 35	6 57	8·2	14	977	6·5				7·79
3000	5 50	7 19	7·8	13	969	6·4				8·10
3100	6 5	7 41	7·4	12	962	6·3				8·42
3200	6 21	8 4	7·1	12	955	6·3				8·74
3300	6 37	8 27	6·7	11	948	6·2				9·06
3400	6 53	8 51	6·4	11	941	6·2				9·38
3500	7 9	9 15	6·1	10	933	6·1				9·70
3600	7 25	9 40	5·9	10	926	6·0				10·0
3700	7 41	10 5	5·6	9	919	6·0				10·4
3800	7 58	10 30	5·4	9	912	5·9				10·7
3900	8 15	10 56	5·2	9	905	5·9				11·0
4000	8 32	11 22	5·0	8	898	5·8				11·4
4100	8 49	11 48	4·8	8	892	5·8				11·7
4200	9 6	12 15	4·6	8	886	5·7				12·0
4300	9 24	12 42	4·4	7	880	5·7				12·4
4400	9 42	13 9	4·3	7	874	5·6				12·7
4500	10 0	13 37	4·1	7	868	5·6				13·0
4600	10 18	14 5	4·0	7	862	5·5				13·3
4700	10 36	14 33	3·9	6	856	5·5				13·7
4800	10 55	15 2	3·7	6	850	5·5				14·0
4900	11 14	15 31	3·6	6	844	5·4				14·4
5000	11 33	16 0	3·5	6	839	5·4				14·7
5100	11 52	16 30	3·4	6	834	5·3				15·1
5200	12 12	17 0	3·3	5	828	5·3				15·4
5300	12 32	17 31	3·2	5	823	5·2				15·8
5400	12 52	18 2	3·1	5	817	5·2				16·2
5500	13 12	18 33	3·0	5	812	5·2				16·5

There is not sufficient data for a precise estimate of the accuracy of this gun.
The accuracy on a vertical target is, however, approximately equal to that of the 7-inch R.M.L. gun of $6\frac{1}{2}$ tons, whilst the accuracy in length is somewhat better owing to the larger angles of descent at similar ranges.

Fuze Scale. 15 seconds Wood Time Fuze.

yards.	tenths.
240	1·0
325	1·5
410	2·0
495	2·5
580	3·0
660	3·5
740	4·0
810	4.5
880	5·0
955	5·5
1030	6·0
1105	6·5
1180	7·0
1255	7·5
1330	8·0
1405	8·5
1480	9·0
1555	9·5
1630	10·0
1705	10·5
1780	11·0
1855	11·5
1930	12·0
2005	12·5
2080	13·0
2155	13·5
2225	14·0
2300	14·5
2370	15·0
2440	15·5
2505	16·0
2575	16·5
2640	17·0
2705	17·5
2770	18·0
2835	18·5
2900	19·0
2965	19·5
3030	20·0
3090	20·5
3165	21·0
3235	21·5
3300	22·0
3365	22·5
3430	23·0
3495	23·5
3560	24·0
3625	24·5
3690	25·0
3755	25·5
3820	26·0
3885	26·5
3945	27·0
4010	27·5
4070	28·0
4135	28·5
4195	29·0
4255	29·5
4310	30·0

* To obtain this density of loading, the base of shell when home should be 20·3 inches from the bottom of the bore.

Range Table for 8-inch R.M.L. Gun.

Based on Practice of 11. 11. 85.

Charge, 21 lbs. P.
Projectile, common, weight 180 lb.
Muzzle velocity, 1040 f.s.
Carriage, W.I., naval.
Jump, 6 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	Time of Flight.	Fuze Scale. 15 seconds Wood Time.	
yards.	° ′	° ′	f.s.	yards.	yards.	secs.	yards.	tenths.
0							220	1·0
100	0 9	0 16	1031			0·29	305	1·5
200	0 24	0 32	1022	31	0·29	0·58	385	2·0
300	0 39	0 49	1014	31	0·43	0·88	455	2·5
400	0 54	1 6	1006	31	0·58	1·18	525	3·0
500	1 10	1 23	998	30	0·72	1·48	595	3·5
600	1 26	1 40	990	30	0·87	1·78	665	4·0
700	1 42	4 58	982	30	1·01	2·08	735	4·5
800	1 58	2 16	974	30	1·16	2·38	805	5·0
900	2 15	2 34	967	29	1·31	2·69	875	5·5
1000	2 32	2 53	960	29	1·45	3·0	940	6·0
1100	2 49	3 11	953	29	1·60	3·32	1010	6·5
1200	3 6	3 30	946	28	1·74	3·64	1075	7·0
1300	3 24	3 50	939	28	1·89	3·96	1145	7·5
1400	3 42	4 10	932	28	2·03	4·28	1210	8·0
1500	4 0	4 30	925	28	2·18	4·61	1280	8·5
1600	4 18	4 51	918	28	2·32	4·94	1345	9·0
1700	4 36	5 12	911	27	2·47	5·27	1415	9·5
1800	4 55	5 33	904	27	2·61	5·6	1480	10·0
1900	5 4	5 55	897	27	2·76	5·93	1550	10·5
2000	5 33	6 18	891	26	2·91	6·26	1615	11·0
2100	5 53	6 41	885	26	3·05	6·6	1685	11·5
2200	6 13	7 4	879	26	3·20	6·94	1750	12·0
2300	6 33	7 28	873	25	3·34	7·29	1820	12·5
2400	6 53	7 53	867	25	3·49	7·64	1885	13·0
2500	7 14	8 18	861	25	3·63	7·99	1955	13·5
2600	7 35	8 43	855	24	3·78	8·34	2020	14·0
2700	7 56	9 9	849	24	3·92	8·69	2085	14·5
2800	8 17	9 36	843	24	4·07	9·04	2150	15·0
2900	8 38	10 3	837	23	4·21	9·39	2215	15·5
3000	9 0	10 30	831	23	4·36	9·75	2280	16·0
3100	9 22	10 58	825	23	4·51	10·11	2350	16·5
3200	9 44	11 27	820	22	4·65	10·47	2415	17·0
3300	10 6	11 57	815	22	4·80	10·84	2480	17·5
3400	10 28	12 27	810	22	4·94	11·21	2545	18·0
3500	10 50	12 58	805	21	5·09	11·58	2610	18·5
3600	11 12	13 30	800	21	5·23	11·95	2675	19·0
3700	11 35	14 4	795	21	5·38	12·32	2740	19·5
3800	11 58	14 38	790	20	5·52	12·69	2800	20·0
3900	12 21	15 13	785	20	5·67	13·06	2860	20·5
4000	12 44	15 49	780	20	5·81	13·44	2920	21·0
							2975	21·5
							3035	22·0
							3095	22·5
							3150	23·0
							3210	23·5
							3265	24·0
							3325	24·5
							3380	25·0
							3440	25·5
							3495	26·0
							3550	26·5
							3605	27·0
							3660	27·5
							3715	28·0
							3770	28·5
							3825	29·0
							3880	29·5
							3930	30·0

Range Table for 7-inch R.M.L. Gun of 7 tons.

Based on Calculation.

Charge, 30 lbs. P.
Gravimetric density, $\frac{28\cdot0}{0\cdot990}$ (about).
Projectile, Palliser, weight, 115 lbs.
Carriage, iron, garrison.
Jump, 10 minutes.
Muzzle velocity, 1561 f.s.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each range	50 per Cent. of rounds should fall within: Length.	Breadth.	Height.	Time of Flight.
yds.	° ′	° ′	f.s.	yards.	yards.	yards.	yards.	feet.	seconds.
0									
100		0 7	1532			44	0·1	0·3	0·20
200	0 2	0 15	1503	64	0·28	44	0·2	0·6	0·40
300	0 9	0 23	1476	63	0·43	44	0·3	1·0	0·60
400	0 16	0 31	1448	63	0·58	43	0·4	1·3	0·80
500	0 23	0 39	1421	62	0·72	43	0·5	1·6	1·02
600	0 30	0 48	1394	62	0·87	43	0·6	2·0	1·23
700	0 38	0 57	1368	61	1·01	43	0·7	2·4	1·35
800	0 46	1 6	1344	60	1·16	43	0·8	2·7	1·67
900	0 54	1 15	1320	60	1·31	43	0·9	3·1	1·89
1000	1 2	1 24	1296	59	1·45	43	1·0	3·5	2·12
1100	1 10	1 34	1274	58	1·60	43	1·1	3·9	2·35
1200	1 19	1 44	1252	57	1·74	42	1·2	4·4	2·59
1300	1 28	1 56	1231	56	1·89	42	1·3	4·9	2·84
1400	1 37	2 8	1211	55	2·03	43	1·5	5·5	3·09
1500	1 46	2 20	1191	54	2·18	43	1·6	6·0	3·35
1600	1 55	2 32	1172	53	2·32	44	1·7	6·6	3·61
1700	2 5	2 45	1153	52	2·47	44	1·8	7·1	3·87
1800	2 15	2 58	1134	51	2·61	44	1·9	7·7	4·13
1900	2 25	3 12	1116	50	2·76	44	2·1	8·3	4·39
2000	2 35	3 26	1098	49	2·91	45	2·2	9·0	4·75
2100	2 46	3 40	1085	48	3·05	45	2·3	9·7	4·92
2200	2 57	3 55	1071	47	3·20	46	2·4	10·0	5·29
2300	3 8	4 10	1058	47	3·34	46	2·6	11·0	5·56
2400	3 20	4 26	1046	46	3·49	47	2·7	12·0	5·84
2500	3 32	4 43	1035	45	3·63	47	2·8	13·0	6·12
2600	3 44	5 0	1025	44	3·78	48	2·9	14·0	6·40
2700	3 57	5 18	1015	43	3·92	48	3·1	15·0	6·68
2800	4 10	5 36	1005	42	4·07	49	3·2	16·0	6·97
2900	4 23	5 55	995	41	4·21	49	3·3	17·0	7·26
3000	4 36	6 14	985	40	4·36	50	3·5	18·0	7·55
3100	4 50	6 35	976	39	4·51				7·85
3200	5 4	6 56	967	38	4·65				8·15
3300	5 18	7 18	958	37	4·80				8·45
3400	5 33	7 40	949	36	4·94				8·76
3500	5 48	8 3	940	35	5·09				9·08
3600	6 4	8 26	931	34	5·23				9·40
3700	6 23	8 51	922	34	5·38				9·73
3800	6 36	9 17	914	33	5·52				10·06
3900	6 52	9 43	906	32	5·67				10·40
4000	7 8	10 9	898	32	5·81				10·75
4100	7 25	10 35	890	31	5·96				11·1

Fuze Scale. 15 seconds M.L. Wood Time.	
yards.	tenths.
260	1·0
350	1·5
440	2·0
530	2·5
620	3·0
710	3·5
800	4·0
890	4·5
980	5·0
1075	5·5
1160	6·0
1245	6·5
1325	7·0
1405	7·5
1480	8·0
1555	8·5
1630	9 0
1705	9·5
1780	10·0
1855	10·5
1920	11·0
1995	11·5
2080	12·0
2165	12·5
2230	13·0
2305	13·5
2375	14·0
2445	14·5
2515	15·0
2585	15·5
2655	16·0
2725	16·5
2795	17·0
2865	17·5
2935	18·0
3005	18·5
3075	19·0
3145	19·5
3215	20·0
3285	20·5
3355	21·0
3425	21·5
3495	22·0
3565	22·5
3635	23·0
3705	23·5
3775	24·0
3840	24·5
3905	25·0
3970	25·5
4035	26·0
4100	26·5

Range Table for 7-inch R.M.L. Gun of $6\frac{1}{2}$ tons.
Based on Practice of 17 and 18. 11. 70.

Charge, 30 lb. P.
Projectile, weight 115 lbs.
Muzzle velocity, 1525 f.s.

Gravimetric density, $\frac{28 \cdot 0}{0 \cdot 990}$ (about).*
Mounting, iron, garrison.
Jump, 10 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 ft. high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	50 per Cent. of Rounds should fall within: Length.	Breadth.	Height.	Time of Flight.
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	ft.	secs.
0					1525	9·2	43			
100		0 7	490	818	1496	9·0	43	0·1	0·3	0·20
200	0 4	0 15	229	362	1468	8·8	43	0·2	0·6	0·40
300	0 12	0 23	150	250	1440	8·7	43	0·3	1·0	0·61
400	0 20	0 32	107	179	1413	8·5	43	0·4	1·3	0·83
500	0 28	0 41	84	140	1387	8·3	43	0·5	1·6	1·05
600	0 36	0 50	69	115	1362	8·2	43	0·6	2·0	1·27
700	0 45	1 0	57	95	1337	8·0	43	0·7	2·4	1·50
800	0 53	1 10	49	82	1313	7·8	43	0·8	2·7	1·74
900	1 2	1 21	42	71	1290	7·7	43	0·9	3·1	1·98
1000	1 11	1 32	37	62	1268	7·5	43	1·0	3·5	2·23
1100	1 20	1 43	33	56	1246	7·4	43	1·1	3·9	2·47
1200	1 29	1 55	30	50	1224	7·2	43	1·2	4·4	2·72
1300	1 39	2 7	27	45	1203	7·1	43	1·3	4·9	2·97
1400	1 49	2 20	25	41	1183	6·9	43	1·5	5·5	3·23
1500	1 59	2 33	22	37	1162	6·7	43	1·6	6·0	3·49
1600	2 10	2 46	20	34	1144	6·6	44	1·7	6·6	3·75
1700	2 21	3 0	19	32	1127	6·5	44	1·8	7·1	4·01
1800	2 32	3 14	18	30	1111	6·3	44	1·9	7·7	4·28
1900	2 43	3 29	16	27	1095	6·2	44	2·1	8·3	4·55
2000	2 55	3 45	15	25	1080	6·1	45	2·2	9·0	4·82
2100	3 7	4 2	14	24	1066	6·0	45	2·3	9·7	5·10
2200	3 19	4 19	13	22	1054	5·9	46	2·4	10	5·38
2300	3 31	4 37	12	21	1042	5·9	46	2·6	11	5·67
2400	3 43	4 55	12	19	1031	5·8	47	2·7	12	5·96
2500	3 56	5 14	11	18	1020	5·7	47	2·8	13	6·25
2600	4 9	5 33	10	17	1009	5·6	48	2·9	14	6·55
2700	4 22	5 53	9·7	16	999	5·6	48	3·1	15	6·85
2800	4 36	6 14	9·2	15	990	5·5	49	3·2	16	7·16
2900	4 49	6 35	8·7	14	981	5·4	49	3·3	17	7·47
3000	5 3	6 57	8·2	14	972	5·4	50	3·5	18	7·78
3100	5 17	7 19	7·8	13	963	5·3				8·09
3200	5 32	7 42	7·4	12	954	5·3				8·40
3300	5 47	8 5	7·0	12	945	5·2				8·72
3400	6 2	8 28	6·7	11	937	5·2				9·04
3500	6 17	8 52	6·4	11	929	5·1				9·36
3600	6 32	9 16	6·1	10	921	5·1				9·68
3700	6 48	9 41	5·9	10	914	5·1				10·0
3800	7 4	10 6	5·6	9	906	5·0				10·3
3900	7 20	10 32	5·4	9	898	5·0				10·7
4000	7 36	10 59	5·1	9	891	4·9				11·0
4100	7 53	11 26	4·9	8	883	4·9				11·3
4200	8 10	11 54	4·7	8	876	4·8				11·7
4300	8 28	12 23	4·6	8	868	4·8				12·0
4400	8 46	12 52	4·4	7	861	4·8				12·4
4500	9 4	13 22	4·2	7	854	4·7				12·7
4600	9 23	13 53	4·0	7	847	4·7				13·1
4700	9 42	14 24	3·9	6	841	4·6				13·4
4800	10 1	14 56	3·7	6	834	4·6				13·8
4900	10 21	15 29	3·6	6	828	4·5				14·2
5000	10 41	16 2	3·5	6	821	4·5				14·5
5100	11 3	16 35	3·4	6	815	4·5				14·9
5200	11 23	17 8	3·2	5	808	4·4				15·3
5300	11 45	17 42	3·1	5	802	4·4				15·7
5400	12 7	18 16	3·0	5	796	4·3				16·0
5500	12 29	18 50	2·9	5	790	4·3				16·4

Fuze Scale. 15 Secs. M.L. Wood Time. yds.	tenths.
250	1·0
340	1·5
430	2·0
520	2·5
610	3·0
695	3·5
780	4·0
865	4·5
945	5·0
1025	5·5
1110	6·0
1190	6·5
1265	7·0
1345	7·5
1420	8·0
1500	8·5
1575	9·0
1650	9·5
1720	10·0
1795	10·5
1865	11·0
1945	11·5
2020	12·0
2090	12·5
2160	13·0
2230	13·5
2300	14·0
2370	14·5
2440	15·0
2510	15·5
2580	16·0
2650	16·5
2720	17·0
2790	17·5
2860	18·0
2930	18·5
3000	19·0
3070	19·5
3135	20·0
3205	20·5
3270	21·0
3335	21·5
3400	22·0
3465	22·5
3530	23·0
3595	23·5
3660	24·0
3725	24·5
3790	25·0
3855	25·5
3920	26·0
3985	26·5
4050	27·0
4115	27·5
4180	28·0
4245	28·5
4310	29·0
4375	29·5
4435	30·0

* To obtain this density of charge, the base of shell when home should be 22·5 inches from the bottom of the bore.

RANGE TABLE FOR 7-INCH R.M.L. GUN OF 90 CWT.

Based on Practice of 5. 6. 84, 9. 9. 84, 22. 10. 84.

Charge, 22 lb. P.
Projectile, weight 115 lb.
Mounting, Naval slide with hydraulic buffer.

*Gravimetric density, $\frac{28 \cdot 0}{\cdot 990}$.
Muzzle velocity, 1325 f.s.
Jump, 12 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Penetration, Wrought Iron.	Slope of Descent.	To hit an object 10 ft. high, the range must be known within	Time of Flight.	Fuze Scale. 15 seconds Wood Time Fuze. Range.	Fuze.
yards.	° ′	° ′	f.s.	inches.	1 in	yards.	seconds.	yards.	tenths.
0			1325	7·9					
100		0 9	1302	7·7	382	643	0·24	240	1·0
200	0 5	0 19	1279	7·6	181	302	0·49	320	1·5
300	0 15	0 29	1257	7·4	119	199	0·74	400	2·0
400	0 25	0 40	1236	7·3	86	143	0·99	470	2·5
500	0 36	0 51	1215	7·1	67	112	1·24	540	3·0
600	0 47	1 3	1195	7·0	55	91	1·49	610	3·5
700	0 58	1 15	1175	6·8	46	76	1·75	680	4·0
800	1 9	1 28	1156	6·7	39	65	2·01	750	4·5
900	1 21	1 41	1138	6·6	34	57	2·28	820	5·0
1000	1 33	1 55	1121	6·5	30	50	2·55	890	5·5
1100	1 45	2 9	1103	6·4	27	44	2·82	960	6·0
1200	1 57	2 24	1087	6·3	24	40	3·10	1035	6·5
1300	2 10	2 39	1072	6·2	22	36	3·38	1105	7·0
1400	2 23	2 55	1059	6·1	20	33	3·66	1180	7·5
1500	2 36	3 11	1047	6·0	18	30	3·95	1250	8·0
1600	2 49	3 27	1036	5·9	16	28	4·24	1320	8·5
1700	3 2	3 44	1025	5·8	15	26	4·53	1390	9·0
1800	3 16	4 2	1015	5·8	14	24	4·83	1460	9·5
1900	3 30	4 20	1005	5·7	13	22	5·13	1530	10·0
2000	3 44	4 39	996	5·6	12	20	5·43	1600	10·5
2100	3 58	4 58	987	5·5	11	19	5·73	1670	11·0
2200	4 12	5 18	978	5·5	11	18	6·04	1740	11·5
2300	4 26	5 38	969	5·4	10	17	6·35	1805	12·0
2400	4 42	5 59	960	5·4	9·6	16	6·66	1875	12·5
2500	4 57	6 20	951	5·3	9·0	15	6·97	1940	13·0
2600	5 12	6 41	943	5·3	8·6	14	7·28	2005	13·5
2700	5 28	7 3	935	5·2	8·1	14	7·60	2070	14·0
2800	5 44	7 25	927	5·2	7·7	13	7·92	2135	14·5
2900	6 0	7 47	919	5·1	7·4	12	8·24	2200	15·0
3000	6 16	8 10	912	5·1	7·0	12	8·56	2265	15·5
3100	6 33	8 33	904	5·0	6·7	11	8·89	2330	16·0
3200	6 50	8 57	896	5·0	6·4	11	9·22	2395	16·5
3300	7 7	9 21	889	4·9	6·1	10	9·55	2455	17·0
3400	7 24	9 45	881	4·9	5·9	10	9·88	2520	17·5
3500	7 41	10 10	874	4·8	5·6	9	10·22	2580	18·0
3600	7 59	10 35	866	4·8	5·3	9	10·56	2640	18·5
3700	8 17	11 1	859	4·7	5·1	9	10·90	2700	19·0
3800	8 35	11 27	852	4·7	4·9	8	11·24	2760	19·5
3900	8 53	11 54	845	4·6	4·7	8	11·6	2820	20·0
4000	9 11	12 22	839	4·6	4·6	8	11·95	2880	20·5
4100	9 30	12 51	832	4·5	4·4	7	12·3	2940	21·0
4200	9 49	13 20	826	4·5	4·2	7	12·65	3000	21·5
4300	10 8	13 50	819	4·4	4·1	7	13·0	3060	22·0
4400	10 27	14 21	813	4·4	3·9	7	13·4	3115	22·5
4500	10 46	14 52	806	4·3	3·8	6	13·7	3175	23·0
4600	11 6	15 24	800	4·3	3·6	6	14·1	3235	23·5
4700	11 26	15 56	794	4·3	3·5	6	14·5	3290	24·0
4800	11 46	16 28	788	4·2	3·4	6	14·8	3345	24·5
4900	12 6	17 1	782	4·2	3·3	6	15·2	3400	25·0
5000	12 27	17 34	776	4·1	3·2	5	15·6	3455	25·5
5100	12 48	18 7	770	4·1	3·1	5	16·0	3510	26·0
5200	13 9	18 41	764	4·1	3·0	5	16·4	3565	26·5
5300	13 30	19 15	759	4·0	2·9	5	16·8	3620	27·0
5400	13 52	19 49	753	4·0	2·8	5	17·2	3675	27·5
5500	14 14	20 24	747	3·9	2·7	4	17·6	3730	28·0
								3780	28·5
								3835	29·0
								3890	29·5
								3940	30·0

There is not sufficient data for a precise estimate of the accuracy of this gun; it is, however, very indiffierent, as the following figures will show:—

50 per cent. of rounds should fall within—

	Yards.	Length. Yards.	Breadth. Yards.	Height. Feet.
Approximate accuracy at	1000	60	2	6
	2000	65	5	16

* To obtain this gravimetric density, the base of the shell when home should be 16¾ inches from the bottom of the bore.

Range Table for 7-inch R.M.L. Gun of 90 cwt., or 6½ tons.

Based on Practice, 5. 6. 84., 9. 9. 84., 22. 10. 84.

Charge, 17 lb. P. Gravimetric density, $\frac{28 \cdot 0}{\cdot 990}$.*
Projectile, weight 115 lbs.

Mounting, naval slide with hydraulic buffer.
Muzzle velocity, 1175 f.s.
Jump, 12 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an Object 10 feet high, Range must be known within	Time of Flight.	Fuze Scale, 15-secs. Wood Time Fuze.	
							Fuze.	Range.
yds.	° ′	° ′	f.s.	1 in	yds.	secs.	yds.	tenths.
0							220	1·0
100	0 2	0 14	1156	246	410	0·26	295	1·5
200	0 14	0 27	1138	127	212	0·53	370	2·0
300	0 26	0 40	1120	86	163	0·80	440	2·5
400	0 39	0 53	1103	65	106	1·07	510	3·0
							580	3·5
500	0 52	1 7	1087	51	86	1·35	650	4·0
600	1 5	1 21	1072	42	71	1·63	720	4·5
700	1 18	1 36	1059	36	60	1·91	790	5·0
800	1 32	1 51	1047	31	52	2·20	860	5·5
900	1 46	2 7	1036	27	45	2·49	930	6·0
							1000	6·5
1000	2 0	2 23	1025	24	40	2·78	1075	7·0
1100	2 14	2 40	1015	21	36	3·08	1145	7·5
1200	2 29	2 57	1005	19	32	3·38	1220	8·0
1300	2 44	3 15	996	18	29	3·68	1290	8·5
1400	3 0	3 33	987	16	27	3·98	1360	9·0
							1430	9·5
1500	3 15	3 52	978	15	25	4·29	1500	10·0
1600	3 31	4 12	969	14	23	4·60	1565	10·5
1700	3 47	4 33	960	13	21	4·91	1635	11·0
1800	4 3	4 54	951	12	19	5·23	1700	11·5
1900	4 20	5 16	943	11	18	5·55	1765	12·0
							1830	12·5
2000	4 37	5 38	935	10	17	5·87	1895	13·0
2100	4 54	6 1	927	9·5	16	6·19	1960	13·5
2200	5 12	6 24	919	8·9	15	6·51	2025	14·0
2300	5 30	6 48	912	8·4	14	6·84	2090	14·5
2400	5 48	7 12	904	7·9	13	7·17	2150	15·0
							2215	15·5
2500	6 7	7 37	896	7·5	12	7·50	2275	16·0
2600	6 26	8 2	889	7·1	12	7·84	2335	16·5
2700	6 45	8 27	881	6·7	11	8·18	2395	17·0
2800	7 4	8 53	874	6·4	11	8·53	2455	17·5
2900	7 24	9 19	866	6·1	10	8·88	2515	18·0
							2575	18·5
3000	7 44	9 45	859	5·8	10	9·23	2635	19·0
3100	8 4	10 12	852	5·6	9	9·58	2695	19·5
3200	8 24	10 39	845	5·3	9	9·94	2750	20·0
3300	8 45	11 7	839	5·1	8	10·30	2810	20·5
3400	9 6	11 35	832	4·9	8	10·66	2865	21·0
							2920	21·5
3500	9 27	12 4	826	4·7	8	11·03	2975	22·0
3600	9 48	12 33	819	4·5	7	11·4	3030	22·5
3700	10 10	13 3	813	4·3	7	11·8	3085	23·0
3800	10 32	13 33	806	4·1	7	12·1	3140	23·5
3900	10 54	14 4	800	4·0	7	12·4	3195	24·0
							3250	24·5
4000	11 16	14 35	794	3·8	6	12·8	3300	25·0
							3355	25·5
							3405	26·0
							3460	26·5
							3510	27·0
							3560	27·5
							3610	28·0
							3660	28·5
							3710	29·0
							3760	29·5
							3810	30·0

* To obtain this gravimetric density, the base of the shell when home should be 13¼ inches from the bottom of the bore.

Range Table for 7-inch R.M.L. Gun of 90 cwt.

Double shell.

Charge, 22 lb. P.
Projectile, double shell, weight 160 lbs.

Range.	Elevation.	Fuze Scale for 15 Seconds M.L. Wood Time Fuze.	
Yards.	° ′	Yards.	Fuze.
100	0 2	200	1·0
200	0 15	285	1·5
300	0 28	370	2·0
400	0 41	450	2·5
500	0 54	520	3·0
600	1 8	590	3·5
700	1 22	660	4·0
800	1 36	730	4·5
900	1 50	800	5·0
1000	2 5	870	5·5
1100	2 20	940	6·0
1200	2 35	1010	6·5
1300	2 50	1080	7·0
1400	3 5	1150	7·5
1500	3 20	1220	8·0
		1290	8·5
		1355	9·0
		1425	9·5
		1490	10·0

This Range Table is based on ranges obtained with shell which were fairly steady, Practice has shown that about half the rounds fired with this charge and projectile are likely to be very unsteady. These unsteady shells may be expected to fall from 100 to 300 yards short of the steady shell.

Range Table for 7-inch R.M.L. Gun.

Based on Practice of 2. 11. 85.

M.V., 1047 f.s.
Charge, 17 lb. S. P., gravimetric density, $\frac{28\cdot0}{\cdot990}$.
Projectile, double shell, weight 160 lbs.
Mounting, W. I., dwarf, traversing.
Jump, 18 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	Time of Flight.
yards.	° ′	° ′	f.s.	yards.	yards.	seconds.
0						
100		0 15	1039			0·30
200	0 12	0 31	1031	33	0·29	0·59
300	0 27	0 47	1024	31	0·43	0·88
400	0 42	1 4	1017	31	0·58	1·17
500	0 58	1 20	1010	31	0·72	1·47
600	1 14	1 37	1003	31	0·87	1·77
700	1 30	1 54	996	31	1·01	2·07
800	1 46	2 12	989	29	1·16	2·37
900	2 3	2 30	982	29	1·31	2·67
1000	2 20	2 48	975	29	1·45	2·98
1100	2 38	3 6	968	29	1·60	3·29
1200	2 56	3 25	962	29	1·74	3·61
1300	3 14	3 44	956	29	1·89	3·93
1400	3 32	4 4	950	28	2·03	4·26
1500	3 50	4 23	944	28	2·18	4·59
1600	4 9	4 42	938	28	2·32	4·92
1700	4 28	5 2	932	27	2·47	5·26
1800	4 48	5 23	926	27	2·61	5·60
1900	5 7	5 44	920	27	2·76	5·95
2000	5 27	6 4	914	27	2·91	6·30

Fuze Scale.	
yards.	tenths.
350	2·0
420	2·5
490	3·0
560	3·5
630	4·0
700	4·5
770	5·0
840	5·5
910	6·0
980	6·5
1045	7·0
1115	7·5
1180	8·0
1250	8·5
1315	9·0
1385	9·5
1450	10·0
1520	10·5
1585	11·0
1655	11·5
1720	12·0
1785	12·5
1850	13·0
1915	13·5
1980	14·0
2000	14·5
2100	15·0

Range Table for 80-pr. R.M.L. Gun.

Based on Practice on 8. 10. 84. and 15. 10. 84.

Mounting, wood garrison sliding carriage on dwarf traversing platform.
Calibre of gun, 6·3 inches.
Jump, 5 minutes.
Charge, 20 lb. P. Gravimetric density, $\frac{26\cdot8}{1\cdot035}$.
Projectile, studded common, or shrapnel shell, without gas-check; weight, 80 lb.
Muzzle velocity, 1558 f.s.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	Time of Flight.	Fuze Scale.	
							Range.	Fuze.
yards.	° ′	° ′	f.s.	yards.	yards.	seconds.	yards.	tenths.
0								
100			1520					
200	0 10	0 16	1487	62·2	0·29	0·40	240	1·0
300	0 18	0 29	1454	59·4	0·43	0·61	320	1·5
400	0 27	0 42	1423	57·7	0·58	0·82	400	2·0
500	0 36	0 56	1392	55·1	0·72	1·04	480	2·5
600	0 45	1 10	1362	52·6	0·87	1·26	560	3·0
700	0 55	1 24	1333	50·2	1·01	1·49	640	3·5
800	1 5	1 39	1305	47·9	1·16	1·72	720	4·0
900	1 15	1 54	1278	45·7	1·31	1·95	800	4·5
1000	1 25	2 10	1256	43·6	1·45	2·18	880	5·0
1100	1 35	2 25	1234	41·6	1·60	2·42	960	5·5
1200	1 45	2 40	1212	39·7	1·74	2·76	1040	6·0
1300	1 55	2 55	1192	38·4	1·89	3·01	1120	6·5
1400	2 5	3 10	1170	37·5	2·03	3·26	1200	7·0
1500	2 15	3 25	1159	36·8	2·18	3·51	1280	7·5
1600	2 26	3 41	1129	36·1	2·32	3·77	1360	8·0
1700	2 37	3 57	1109	35·4	2·47	4·03	1440	8·5
1800	2 48	4 13	1089	34·8	2·61	4·30	1520	9·0
1900	3 0	4 30	1069	34·2	2·76	4·58	1600	9·5
2000	3 12	4 47	1049	33·6	2·91	4·77	1680	10·0
2100	3 24	5 5	1031	33·0	3·05	5·06	1755	10·5
2200	3 36	5 24	1015	32·4	3·20	5·36	1830	11·0
2300	3 48	5 44	1001	31·8	3·34	5·67	1905	11·5
2400	4 0	6 4	989	31·2	3·49	5·99	1980	12·0
2500	4 13	6 25	978	30·6	3·63	6·31	2060	12·5
2600	4 26	6 46	968	30·1	3·78	6·64	2140	13·0
2700	4 39	7 8	959	29·6	3·92	6·97	2215	13·5
2800	4 52	7 31	950	29·1	4·07	7·31	2290	14·0
2900	5 5	7 51	941	28·6	4·21	7·65	2365	14·5
3000	5 18	8 17	932	28·1	4·36	7·97	2440	15·0
3100	5 32	8 40	923	27·6	4·51	8·29	2515	15·5
3200	5 46	9 3	914	27·1	4·65	8·61	2590	16·0
3300	6 0	9 26	905	26·6	4·80	8·93	2660	16·5
3400	6 14	9 50	896	26·1	4·94	9·25	2730	17·0
3500	6 28	10 14	887	25·6	5·09	9·68	2795	17·5
3600	6 43	10 38	879	25·1	5·23	10·01	2860	18·0
3700	6 59	11 2	871	24·6	5·38	10·34	2930	18·5
3800	7 16	11 26	863	24·1	5·52	10·66	3000	19·0
3900	7 33	11 50	855	23·6	5·67	11·00	3070	19·5
4000	7 59	12 14	847	23·1	5·81	11·33	3140	20·0
4100	8 8	12 38	839	22·6	5·96	11·67	3210	20·5
4200	8 26	12 52	831	22·1	6·11	12·02	3280	21·0
4300	8 44	13 16	823	21·6	6·25	12·36	3345	21·5
4400	9 2	13 41	816	21·2	6·40	12·71	3410	22·0
4500	9 20	14 6	809	20·8	6·54	13·07	3475	22·5
4600	9 38	14 31	802	20·4	6·69	13·44	3540	23·0
4700	9 56	14 57	795	20·0	6·84	13·81	3605	23·5
4740	10 0	15 6	792	19·8	6·88	14·00	3670	24·0
							3735	24·5
							3800	25·0
							3865	25·5
							3930	26·0
							3995	26·5
							4060	27·0
							4120	27·5
							4180	28·0
							4240	28·5
							4300	29·0
							4360	29·5
							4420	30·0

Range Table for 80-pr. R.M.L. Gun.
Based on Practice of 8. 10. 84. and 15. 10. 84.

Mounting, wood garrison sliding carriage on dwarf traversing platform.
Calibre of Gun, 6·3 inches.
Jump, 5 minutes.

Charge, 20 lb. P., gravimetric density, $\frac{26·8}{1·035}$
Projectile, studless Palliser shell with rotating gas-check; weight, 90 lb.
Muzzle velocity, 1553 f.s.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	Time of Flight.
yards.	° ′	° ′	f.s.	yards.	yards.	seconds.
0						
100			1529			
200	0 13	0 18	1506	55·3	0·29	0·43
300	0 22	0 31	1483	53·3	0·43	0·64
400	0 31	0 44	1461	51·4	0·58	0·85
500	0 40	0 58	1438	49·6	0·72	1·06
600	0 49	1 12	1416	48·0	0·87	1·27
700	0 58	1 29	1394	46·5	1·01	1·49
800	1 7	1 40	1373	45·1	1·16	1·72
900	1 16	1 54	1352	43·8	1·31	1·96
1000	1 25	2 8	1332	42·6	1·45	2·30
1100	1 35	2 23	1312	41·4	1·60	2·44
1200	1 45	2 38	1292	40·3	1·74	2·68
1300	1 55	2 53	1272	39·2	1·89	2·93
1400	2 5	3 8	1253	38·2	2·03	3·18
1500	2 15	3 23	1235	37·3	2·18	3·43
1600	2 26	3 38	1219	36·5	2·32	3·68
1700	2 37	3 53	1203	35·8	2·47	3·94
1800	2 48	4 8	1187	35·1	2·61	4·02
1900	2 59	4 24	1171	34·4	2·76	4·47
2000	3 10	4 40	1155	33·7	2·91	5·74
2100	3 21	4 57	1140	33·0	3·05	5·02
2200	3 32	5 14	1126	32·3	3·20	5·30
2300	3 43	5 32	1112	31·7	3·34	5·58
2400	3 54	5 50	1099	31·1	3·49	5·86
2500	4 6	6 8	1086	30·5	3·63	6·16
2600	4 18	6 27	1074	30·0	3·78	6·46
2700	4 30	6 46	1062	29·5	3·92	6·77
2800	4 42	7 6	1051	29·0	4·07	7·08
2900	4 54	7 26	1041	28·5	4·21	7·39
3000	5 6	7 46	1031	28·0	4·36	7·70
3100	5 19	8 5	1022	27·5	4·51	8·01
3200	5 32	8 24	1014	27·0	4·65	8·33
3300	5 45	8 43	1003	26·5	4·80	8·65
3400	5 58	9 2	998	26·1	4·94	8·97
3500	6 11	9 21	989	25·7	5·09	9·29
3600	6 24	9 40	983	25·3	5·23	9·62
3700	6 37	9 59	975	24·9	5·38	9·96
3800	6 50	10 18	968	24·5	5·52	10·32
3900	7 4	10 38	961	24·1	5·67	10·68
4000	7 18	10 58	954	23·7	5·81	11·05
4100	7 42	11 8	947	23·3	5·96	11·43
4200	7 56	11 28	940	23·0	6·11	11·81
4300	8 10	11 48	933	22·7	6·25	12·15
4400	8 24	12 8	926	22·4	6·40	12·55
4500	8 38	12 28	919	22·1	6·54	12·97
4600	8 52	12 48	912	21·8	6·69	13·40
4700	9 6	13 8	905	21·5	6·84	13·83
4800	9 20	13 29	899	21·2	6·98	14·26
4900	9 35	13 50	893	20·9	7·12	14·69
5000	9 50	14 11	887	20·6	7·26	15·12
5175	10 0	14 26	882	20·4	7·35	15·42

Range Table for 80-pr. R.M.L. Gun (Revised, 10. 85).

Based on Practice of 29. 7. 76.; 8., 15., and 29. 10. 84.; 12. 11. 84.; 1. and 21. 9. 85.

Charge, 12 lb. P. Gravimetric density, $\frac{26 \cdot 0}{1 \cdot 066}$ (about).*
Projectile, 80½ lb.
Mounting, wood, garrison.
Jump, 8 minutes.
Muzzle velocity, 1230 f.s.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Time of Flight
yards.	° ′	° ′	1 in	yards.	f.s.	seconds.
0						
100	0 3	0 11	300	500	1206	0·25
200	0 14	0 23	148	247	1183	0·50
300	0 26	0 35	98	163	1161	0·76
400	0 38	0 48	72	120	1140	1·02
500	0 50	1 2	56	93	1120	1·28
600	1 3	1 16	45	75	1101	1·55
700	1 16	1 31	38	63	1081	1·83
800	1 29	1 46	32	53	1063	2·11
900	1 43	2 2	28	46	1046	2·39
1000	1 57	2 18	25	41	1032	2·68
1100	2 11	2 35	22	37	1020	2·97
1200	2 25	2 52	20	33	1008	3·27
1300	2 40	3 10	18	30	997	3·57
1400	2 55	3 28	16	27	986	3·88
1500	3 10	3 47	15	25	975	4·19
1600	3 25	4 7	14	23	964	4·50
1700	3 41	4 27	13	21	954	4·82
1800	3 57	4 48	12	20	944	5·14
1900	4 13	5 9	11	18	934	5·46
2000	4 30	5 31	10	17	924	5·79
2100	4 47	5 54	9·7	16	914	6·12
2200	5 5	6 17	9·1	15	905	6·45
2300	5 23	6 41	8·6	14	896	6·78
2400	5 41	7 5	8·0	13	887	7·12
2500	6 0	7 31	7·5	13	878	7·46
2600	6 19	7 57	7·1	12	870	7·80
2700	6 38	8 34	6·7	11	862	8·14
2800	6 58	9 2	6·3	10	854	8·49
2900	7 18	9 30	6·0	10	846	8·84
3000	7 39	9 59	5·7	9	838	9·2
3100	8 0	10 29	5·4	9	830	9·6
3200	8 22	11 0	5·2	9	822	9·95
3300	8 44	11 32	4·9	8	814	10·3
3400	9 6	12 5	4·7	8	807	10·7
3500	9 29	12 38	4·5	8	800	11·1
3600	9 52	13 12	4·3	7	793	11·4
3700	10 16	13 47	4·1	7	786	11·8
3800	10 40	14 22	3·9	7	779	12·2
3900	11 4	14 58	3·7	6	772	12·6
4000	11 29	15 34	3·6	6	765	13·0

Fuze scale for 15-seconds M.L. wood time fuze. Based on practice, 8. 10. 84.	
yards.	tenths.
220	1·0
300	1·5
380	2·0
460	2·5
540	3·0
620	3·5
700	4·0
780	4·5
860	5·0
940	5·5
1020	6·0
1100	6·5
1170	7·0
1240	7·5
1310	8·0
1380	8·5
1450	9·0
1520	9·5
1590	10·0
1660	10·5
1730	11·0
1800	11·5
1865	12·0
1930	12·5
1995	13·0
2060	13·5
2125	14·0
2190	14·5
2255	15·0
2320	15·5
2380	16·0
2440	16·5
2500	17·0
2560	17·5
2620	18·0
2680	18·5
2740	19·0
2800	19·5
2860	20·0
2920	20·5
2980	21·0
3040	21·5
3100	22·0
3160	22·5
3220	23·0
3280	23·5
3340	24·0
3400	24·5
3460	25·0
3520	25·5
3580	26·0
3640	26·5
3700	27·0
3760	27·5
3820	28·0
3880	28·5
3935	29·0
3990	29·5
4050	30·0

* To obtain this density the base of the shell when home should be 11·1 inches from the bottom of the bore.

Range Table for 64-pr. R.M.L. Gun, Mark III.

Based on Practice of 10. 2. 85. and 13. 3. 85.

Charge, 8 lb. R.L.G.[2] or R.L.G. or L.G. Gravimetric density, $\frac{28 \cdot 0}{0 \cdot 990}$*

Projectile, common shell, weight 65 lb.
Muzzle velocity, 1260 f.s.
Mounting, siege travelling.
Jump, 10 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	Remaining Velocity.	Time of Flight.	Fuze Scale. 15-seconds M.L. Wood Time Fuze.*	
yds.	° ′	° ′	1 in	f.s.	secs.	yds.	fuze.
0				1260			
100	0 1	0 11	300	1232	0·24	245	1·0
200	0 12	0 23	149	1205	0·49	315	1·5
300	0 23	0 35	98	1179	0·74	385	2·0
400	0 35	0 48	72	1154	1·00	455	2·5
						525	3·0
500	0 47	1 1	56	1131	1·26	595	3·5
600	0 59	1 15	46	1108	1·53	665	4·0
700	1 12	1 29	39	1087	1·80	735	4·5
800	1 25	1 44	33	1067	2·08	805	5·0
900	1 38	1 59	29	1051	2·36	870	5·5
						940	6·0
1000	1 52	2 15	25	1036	2·64	1005	6·5
1100	2 6	2 32	23	1022	2·93	1075	7·0
1200	2 20	2 50	20	1009	3·23	1140	7·5
1300	2 35	3 9	18	996	3·54	1210	8·0
1400	2 50	3 29	16	984	3·85	1275	8·5
						1345	9·0
1500	3 5	3 50	15	972	4·16	1410	9·5
1600	3 21	4 11	14	961	4·47	1480	10·0
1700	3 37	4 33	13	950	4·79	1545	10·5
1800	3 53	4 56	12	939	5·11	1615	11·0
1900	4 10	5 20	11	928	5·43	1680	11·5
						1750	12·0
2000	4 27	5 44	10	917	5·76	1815	12·5
2100	4 44	6 8	9·3	907	6·09	1880	13·0
2200	5 1	6 33	8·7	897	6·42	1950	13·5
2300	5 19	6 58	8·2	887	6·76	2015	14·0
2400	5 37	7 23	7·7	877	7·10	2080	14·5
						2150	15·0
2500	5 55	7 49	7·3	867	7·44	2215	15·5
2600	6 13	8 15	6·9	858	7·79	2280	16·0
2700	6 32	8 42	6·5	849	8·14	2350	16·5
2800	6 50	9 10	6·2	840	8·50	2415	17·0
2900	7 9	9 39	5·9	831	8·86	2480	17·5
						2545	18·0
3000	7 29	10 8	5·6	823	9·22	2610	18·5
3100	7 49	10 38	5·3	815	9·59	2675	19·0
3200	8 10	11 8	5·1	807	9·95	2740	19·5
3300	8 31	11 39	4·8	799	10·3	2800	20·0
3400	8 52	12 10	4·6	791	10·7	2860	20·5
						2920	21·0
3500	9 14	12 42	4·4	783	11·1	2975	21·5
3600	9 36	13 14	4·3	775	11·4	3035	22·0
3700	9 58	13 46	4·1	767	11·8	3095	22·5
3800	10 21	14 19	3·9	759	12·2	3150	23·0
3900	10 44	14 52	3·8	752	12·6	3210	23·5
						3265	24·0
4000	11 8	15 26	3·6	745	13·0	3325	24·5
						3380	25·0
						3440	25·5
						3495	26·0
						3550	26·5
						3605	27·0
						3660	27·5
						3715	28·0
						3770	28·5
						3825	29·0
						3880	29·5
						3930	30·0

* The shell should be rammed to 7·3 inches from the bottom of the bore.

Range Table for 64-pr. R.M.L. converted Guns of 58 and 71 cwt.

Based on Practice of 10. 2. 85. and 13. 3. 85.

Charge, 6 lb. R.L.G.², R.L.G. or L.G. Gravimetric density, $\frac{28 \cdot 0}{0 \cdot 990}$*

Projectile, common shell, weight 65 lb.
Muzzle velocity, 1125 f.s.
Mounting, wood, garrison.
Jump, 13 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	Remaining Velocity.	Time of Flight.
yds.	° ′	° ′	1 in	f.s.	secs.
0				1125	
100		0 13	270	1103	0·27
200	0 13	0 27	127	1082	0·54
300	0 26	0 41	84	1063	0·82
400	0 40	0 56	61	1046	1·20
500	0 54	1 11	48	1031	1·38
600	1 8	1 27	40	1017	1·67
700	1 22	1 43	33	1005	1·97
800	1 37	2 0	29	903	2·28
900	1 52	2 17	25	981	2·59
1000	2 7	2 35	22	969	2·91
1100	2 22	2 53	20	958	3·23
1200	2 37	3 12	18	947	3·55
1300	2 53	3 32	16	936	3·87
1400	3 9	3 53	15	925	4·20
1500	3 25	4 15	13	915	4·53
1600	3 42	4 37	12	905	4·86
1700	3 59	5 0	11	895	5·19
1800	4 17	5 24	11	885	5·53
1900	4 35	5 48	9·8	875	5·87
2000	4 53	6 13	9·2	865	6·21
2100	5 12	6 39	8·6	856	6·56
2200	5 31	7 6	8·0	847	6·91
2300	5 51	7 34	7·5	838	7·27
2400	6 11	8 3	7·1	829	7·63
2500	6 33	8 33	6·7	821	7·99
2600	6 54	9 3	6·3	813	8·36
2700	7 16	9 34	5·9	805	8·73
2800	7 38	10 5	5·6	797	9·10
2900	8 1	10 37	5·3	789	9·48
3000	8 24	11 10	5·1	781	9·86
3100	8 47	11 43	4·8	773	10·25
3200	9 11	12 17	4·6	765	10·6
3300	9 36	12 52	4·4	757	11·0
3400	10 2	13 27	4·2	750	11·4
3500	10 28	14 3	4·0	743	11·8
3600	10 55	14 40	3·8	737	12·2
3700	11 22	15 17	3·7	730	12·6
3800	11 50	15 55	3·5	723	13·0
3900	12 19	16 34	3·4	716	13·4
4000	12 48	17 14	3·2	709	13·8

Fuze Scale. 15-seconds M.L. Wood Time Fuze.	
yds.	fuze.
245	1·0
310	1·5
380	2·0
445	2·5
515	3·0
580	3·5
650	4·0
715	4·5
785	5·0
850	5·5
920	6·0
985	6·5
1050	7·0
1115	7·5
1180	8·0
1245	8·5
1310	9·0
1375	9·5
1440	10·0
1505	10·5
1570	11·0
1635	11·5
1700	12·0
1760	12·5
1825	13·0
1885	13·5
1950	14·0
2010	14·5
2075	15·0
2135	15·5
2200	16·0
2260	16·5
2325	17·0
2385	17·5
2450	18·0
2510	18·5
2570	19·0
2630	19·5
2690	20·0
2745	20·5
2805	21·0
2860	21·5
2920	22·0
2975	22·5
3030	23·0
3085	23·5
3140	24·0
3195	24·5
3250	25·0
3305	25·5
3360	26·0
3410	26·5
3460	27·0
3510	27·5
3560	28·0
3610	28·5
3660	29·0
3710	29·5
3770	30·0

* The shell should be rammed to 6·4 inches from the bottom of the bore.

Range Table for 40-pr. R.M.L. Gun, Mark I, 34 cwt.

Based on Practice of 22. 3. and 8. 4. 72.

Length of bore, 7 feet 1½ inches.
Total length, 7 feet 11·65 inches.
Charge, 7 lbs. R.L.G.
Projectile, common shell, filled with sand and plugged.
Weight, 38½ lbs.

Mean elevation due to each 100 yards of range in interpolation.									
Distance of Object.	Elevation.		Time of Flight.	Distance of Object.	Elevation.		Time of Flight.
yds.	°	′	secs.	yds.	°	′	secs.
100	0	10	0·25	2100	4	20	6·00
200	0	20	0·51	2200	4	36	6·33
300	0	30	0·77	2300	4	53	6·66
400	0	40	1·03	2400	5	10	7·00
500	0	50	1·29	2500	5	27	7·34
600	1	1	1·55	2600	5	44	7·69
700	1	12	1·82	2700	6	2	8·05
800	1	24	2·09	2800	6	20	8·41
900	1	36	2·37	2900	6	39	8·77
1000	1	48	2·65	3000	6	58	9·14
1100	2	0	2·93	3100	7	17	9·51
1200	2	12	3·22	3200	7	36	9·88
1300	2	25	3·51	3300	7	56	10·25
1400	2	39	3·81	3400	8	17	10·68
1500	2	53	4·11	3500	8	38	11·02
1600	3	7	4·41	3600	8	59	11·42
1700	3	21	4·72	3700	9	21	11·82
1800	3	35	5·03	3800	9	43	12·23
1900	3	50	5·35	3900	10	5	12·64
2000	4	5	5·67	4000	10	27	13·05

Tenths Fuze.	Yards.
1	205
2	395
3	585
4	775
5	950
6	1125
7	1295
8	1470
9	1630
10	1795
11	1950
12	2105
13	2255
14	2400
15	2545
16	2690
17	2830
18	2965
19	3100
20	3235
21	3370
22	3495
23	3620
24	3745
25	3860
26	3980

The fuze scale was deduced from curve laid down from practice table.

Range Table for 6·6-inch R.M.L. Gun.

Based on Practice of 11. 10. 80.

Carriage, H.P.
Jump, 8 minutes.
Charge, 25 lb. P.

Projectile, battering shell, 100 lb.
Muzzle velocity, 1416 f.s.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	Time of Flight.	Fuze Scale, 15 secs. Time Fuze with detonator.	
yds.	° ′	° ′	f.s.	yds.	yds.	secs.	yds.	tenths.
100		0 6	1389	62·0	0·14	0·25	190	1·0
200	0 8	0 15	1362	60·6	0·28	0·45	279	1·5
300	0 16	0 25	1337	59·2	0·43	0·70	366	2·0
400	0 24	0 34	1312	57·8	0·58	0·91	453	2·5
500	0 32	0 43	1288	56·4	0·72	1·17	540	3·0
600	0 40	0 54	1264	55·0	0·87	1·40	626	3·5
							712	4·0
700	0 49	1 5	1241	53·2	1·01	1·65	800	4·5
800	0 58	1 16	1220	51·6	1·16	1·90	880	5·0
900	1 08	1 28	1199	50·0	1·31	2·15	960	5·5
1000	1 18	1 40	1178	49·2	1·45	2·41	1040	6·0
							1119	6·5
1100	1 28	1 53	1158	48·4	1·60	2·68	1199	7·0
1200	1 38	2 5	1139	47·6	1·74	2·95	1278	7·5
1300	1 48	2 18	1121	46·8	1·89	3·20	1357	8·0
1400	1 58	2 32	1103	46·0	2·03	3·48	1435	8·5
							1512	9·0
1500	2 9	2 47	1086	44·7	2·18	3·75	1589	9·5
1600	2 20	3 33	1071	43·3	2·32	4·00	1666	10·0
							1741	10·5
1700	2 32	3 21	1056	42·0	2·47	4·30	1814	11·0
1800	2 44	3 35	1044	41·0	2·61	4·60	1885	11·5
1900	2 56	3 55	1033	40·0	2·76	4·90	1955	12·0
2000	3 8	4 15	1022	39·0	2·91	5·20	2024	12·5
2100	3 21	4 35	1012	38·0	3·05	5·50	2092	13·0
							2159	13·5
2200	3 34	4 56	1002	37·0	3·20	5·75	2226	14·0
							2292	14·5
2300	3 48	5 17	992	36·0	3·34	6·05	2367	15·0
							2423	15·5
2400	4 2	5 38	982	35·3	3·49	6·40	2489	16·0
2500	4 16	6 0	973	34·5	3·63	6·70	2555	16·5
							2620	17·0
2600	4 30	6 22	963	33·7	3·78	7·00	2686	17·5
							2751	18·0
2700	4 44	6 44	954	33·0	3·92	7·30	2816	18·5
2800	4 59	7 16	945	32·0	4·07	7·60	2882	19·0
2900	5 14	7 40	937	31·0	4·21	7·94	2947	19·5
							3012	20·0
3000	5 30	8 10	928	30·3	4·36	8·26	3079	20·5
3100	5 47	8 40	920	29·6	4·51	8·60	3147	21·0
							3216	21·5
3200	6 4	9 10	912	29·0	4·65	8·90	3286	22·0
3300	6 21	9 36	903	28·4	4·80	9·21	3355	22·5
							3425	23·0
3400	6 38	10 6	895	27·8	4·94	9·52	3495	23·5
3500	6 56	10 38	887	26·4	5·09	9·85	3564	24·0
							3632	24·5
3600	7 15	11 20	880	25·7	5·23	10·20	3700	25·0
3700	8 34	12 5	872	25·0	5·38	10·50	3764	25·5
							3828	26·0
3800	8 54	12 40	854	24·4	5·52	10·82	3892	26·5
3900	9 14	13 20	846	23·8	5·67	11·15	3956	27·0
							4022	27·5
4000	9 35	14 5	839	23·2	5·81	11·50	4088	28·0
4100	9 56	14 45	833	22·6	5·96	11·82	4151	28·5
							4210	29·0
4200	10 18	15 30	826	21·8	6·11	12·20	4265	29·5
							4320	30·0
4300	10 41	16 20	819	20·8	6·25	12·53		
4400	11 5	17 10	812	20·6	6·40	12·88		
4500	11 29	17 55	806	20·4	6·54	13·25		
4600	11 53	18 10	799	20·2	6·69	13·60		
4700	12 17	18 55	794	20·1	6·83	14·00		
4800	12 42	19 10	787	20·0	6·98	14·40		
4900	13 7	19 55	780	20·0	7·13	14·81		
5000	13 32	20 20	774	20·0	7·27	14·92		

RANGE TABLE FOR 40-PR. RIFLED M.L. GUN OF 35 CWT.

Projectile, common shell or shrapnel shell, with gas-check

Charge, 7 lb. R.L.G.², R.L.G. or L.G.
Muzzle velocity, 1425 f.s.
Mounting, siege travelling.
Jump, 11 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each range	50 per cent. of rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Dangerous zone for a height of 6 feet.
yds.	° ′	° ′	f.s.	yds.	yds.	yds.	yds.	yds.	secs.	yds.
0										
100			1392			20	0·08		0·20	
200	0 6	0 18	1359	56	0·29	20	0·16	0·02	0·40	
300	0 15	0 27	1326	53	0·43	20	0·24	0·03	0·65	whole
400	0 24	0 39	1294	51	0·58	20	0·32	0·06	0·90	174
500	0 34	0 48	1262	50	0·72	20	0·40	0·10	1·15	142
600	0 44	1 0	1235	49	0·87	20	0·48	0·14	1·40	115
700	0 54	1 12	1208	48	1·01	20	0·56	0·19	1·65	95·2
800	1 4	1 24	1182	47	1·16	20	0·63	0·25	1·90	81·9
900	1 14	1 38	1156	46	1·31	20	0·71	0·32	2·15	70·1
1000	1 25	1 50	1130	45	1·45	19	0·79	0·40	2·40	62·5
1100	1 36	2 4	1110	44	1·60	19	0·87	0·48	2·65	55·0
1200	1 47	2 19	1091	43	1·74	19	0·94	0·58	2·90	49·0
1300	1 58	2 34	1072	42	1·89	19	1·02	0·69	3·15	44·2
1400	2 9	2 50	1053	41	2·03	19	1·10	0·81	3·40	40·2
1500	2 20	3 6	1034	40	2·18	19	1·17	0·93	3·70	36·8
1600	2 32	3 20	1021	40	2·32	19	1·24	1·06	4·00	34·1
1700	2 44	3 35	1008	39	2·47	19	1·32	1·20	4·30	31·5
1800	2 56	3 55	995	38	2·61	19	1·39	1·37	4·60	29·1
1900	3 9	4 15	982	37	2·76	20	1·46	1·54	4·90	26·8
2000	3 22	4 36	970	36	2·91	21	1·53	1·72	5·20	24·8
2100	3 35	4 50	958	36	3·05	22	1·60	1·90	5·50	23·1
2200	3 49	5 12	947	35	3·20	23	1·69	2·11	5·80	21·5
2300	4 3	5 38	936	34	3·34	23	1·76	2·34	6·10	20·1
2400	4 17	6 1	925	33	3·49	24	1·84	2·60	6·40	18·8
2500	4 32	6 27	914	32	3·63	25	1·91	2·89	6·70	17·5
2600	4 47	6 54	904	31	3·78	26	1·99	3·20	7·00	16·3
2700	5 3	7 25	894	30	3·92	26	2·06	3·52	7·30	15·2
2800	5 19	7 56	884	29	4·07	27	2·13	3·84	7·60	14·2
2900	5 35	8 12	874	29	4·21	28	2·21	4·17	7·95	13·4
3000	5 22	8 46	864	28	4·36	29	2·28	4·50	8·30	12·8
3100	6 9	9 10	855	28	4·51	29	2·36	4·85	8·65	12·2
3200	6 27	9 48	846	27	4·65	30	2·44	5·20	9·00	11·7
3300	6 45	10 5	837	27	4·80	31	2·51	5·60	9·35	11·2
3400	7 3	10 42	828	26	4·94	31	2·59	6·00	9·70	10·7
3500	7 22	11 0	819	26	5·09	32	2·66	6·40	10·05	10·2
3600	7 41	11 20	810	26	5·23	32	2·74	6·80	10·40	9·8
3700	8 0	12 5	802	25	5·38	33	2·82	7·23	10·75	9·4
3800	8 20	12 25	794	25	5·52	34	2·90	7·67	11·10	9·0
3900	8 40	13 15	786	24	5·67	34	2·97	8·11	11·50	8·6
4000	9 0	13 40	778	24	5·81	35	3·05	8·55	11·90	8·2
4100	9 21	14 30	770	23	5·96	35	3·13	9·00	12·30	7·8
4200	9 42	14 50	762	23	6·11	36	3·21	9·45	12·70	7·5
4300	10 3	15 5	754	23	6·25	37	3·28	9·90	13·10	7·4
4400	10 24	15 28	746	23	6·40	37	3·36	10·35	13·50	7·2
4500	10 46	15 45	739	23	6·54	38	3·44	10·80	13·95	7·1

Fuze Scale.

Range. Yards.	Length of Fuze.
220	1·0
320	1·5
420	2·0
520	2·5
620	3·0
720	8·5
820	4·0
920	4·5
1020	5·0
1120	5·5
1220	6·0
1315	6·5
1410	7·0
1505	7·5
1600	8·0
1695	8·5
1790	9·0
1885	9·5
1980	10·0
2070	10·5
2160	11·0
2250	11·5
2340	12·0
2425	12·5
2510	13·0
2595	13·5
2680	14·0
2765	14·5
2850	15·0
2930	15·5
3010	16·0
3090	16·5
3165	17·0
3240	17·5
3315	18·0
3390	18·5
3460	19·0
3530	19·5
3600	20·0
3665	20·5
3730	21·0
3790	21·5
3850	22·0
3910	22·5
3965	23·0
4020	23·5
4070	24·0
4120	24·5
4165	25·0
4210	25·5
4250	26·0
4290	26·5
4325	27·0
4360	27·5
4390	28·0
4420	28·5
4450	29·0
4475	29·5
4500	30·0

Range Table for 25-pr. Rifled M.L. Gun of 18 cwt.

Projectile, common and shrapnel shell, 25 lbs.

Charge, 4 lb. R.L.G.[2] or R.L.G. or L.G.
Carriage, W.I. Travelling.
Jump, 8 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each range	50 per cent. of rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Dangerous zone for a height of 6 feet.
yds.	° ′	° ′	f.s.	yds.	yds.	yds.	yds.	yds.	secs.	yds.
0										
100	0 8	0 10	1317	50·0	0·14	20	0·07	0·10	0·25	
200	0 18	0 20	1284	50·0	0·29	20	0·14	0·20	0·51	
300	0 28	0 30	1252	50·0	0·43	20	0·21	0·35	0·78	
400	0 38	0 42	1220	45·4	0·58	20	0·28	0·50	1·05	164
500	0 49	0 54	1188	45·4	0·72	20	0·35	0·65	1·32	127
600	1 0	1 6	1162	41·6	0·87	20	0·42	0·80	1·60	102
700	1 12	1 20	1137	41·6	1·01	19	0·49	1·00	1·88	85
800	1 24	1 34	1112	41·6	1·16	19	0·56	1·20	2·16	73
900	1 36	1 50	1087	38·4	1·31	19	0·64	1·45	2·45	62
1000	1 49	2 8	1062	38·4	1·45	19	0·72	1·70	2·75	54
1100	2 2	2 27	1046	35·7	1·60	20	0·80	1·95	3·05	48
1200	2 16	2 46	1031	35·7	1·74	20	0·88	2·20	3·30	42
1300	2 30	3 6	1016	33·3	1·89	20	0·96	2·50	3·61	38
1400	2 45	3 26	1001	33·3	2·03	21	1·04	2·85	3·92	34
1500	3 0	3 46	986	31·2	2·18	21	1·12	3·20	4·25	31
1600	3 16	4 8	973	31·2	2·32	22	1·21	3·55	4·58	28
1700	3 32	4 32	960	31·2	2·47	22	1·30	3·95	4·91	26
1800	3 48	4 58	947	31·2	2·61	23	1·39	4·35	5·25	24
1900	4 4	5 24	934	31·2	2·76	24	1·48	4·80	5·60	22
2000	4 20	5 52	922	29·4	2·91	25	1·57	5·25	5·95	20
2100	4 37	6 20	910	27·7	3·05	26	1·66	5·75	6·30	18
2200	4 55	6 50	899	27·7	3·20	28	1·75	6·25	6·65	17
2300	5 13	7 20	888	26·3	3·34	30	1·85	6·80	7·01	16
2400	5 32	7 52	877	25·0	3·49	31	1·95	7·40	7·38	15
2500	5 52	8 24	866	25·0	3·63	33	2·05	8·00	7·75	14
2600	6 12	8 58	856	23·8	3·78	35	2·15	8·70	8·12	13
2700	6 33	9 32	846	22·7	3·92	36	2·25	9·40	8·50	12
2800	6 55	10 6	836	22·7	4·07	38	2·35	10·25	8·88	11·25
2900	7 17	10 42	826	21·7	4·21	39	2·45	11·20	9·26	10·50
3000	7 40	11 20	817	21·7	4·36	40	2·55	12·25	9·64	10·00
3100	8 3	11 58	808	21·7	4·51	42	2·65	13·50	10·03	9·50
3200	8 26	12 38	799	20·8	4·65	44	2·75	14·80	10·42	9·00
3300	8 50	13 20	790	20·0	4·80	46	2·85	16·10	10·82	8·50
3400	9 15	14 4	781	18·5	4·94	48	2·96	17·45	11·23	8·00
3500	9 42	14 50	772	18·5	5·09	50	3·07	18·80	11·65	7·50
3600	10 9	15 36	763	18·5	5·23	52	3·18		12·07	7·00
3700	10 36	16 24	754	17·8	5·38	54	3·29		12·49	6·50
3800	11 4	17 14	746	17·8	5·52	55	3·40		12·91	5·25
3900	11 32	18 4	738	17·2	5·67	58	3·52		13·33	6·00
4000	12	18 57	730	16·6	5·81	60	3·64		13·75	5·75
4100	12 31	19 51	722	16·1	5·96				14·17	5·50
	13 2	20 48	714	15·6	6·11				14·59	5·25
4200	13 34	21 48	706	15·1	6·25				15·02	5·00
4300	14 7	22 52	698	15·1	6·40				15·45	4·75
4400										
4500	14 40	23 59	691	14·7	6·54				15·90	4·50

Fuze Scale: Range, Yards.	Length of Fuze.
210	1·0
300	1·5
390	2·0
480	2·5
570	3·0
660	3·5
750	4·0
840	4·5
930	5·0
1020	5·5
1100	6·0
1180	6·5
1260	7·0
1340	7·5
1420	8·0
1500	8·5
1580	9·5
1660	9·5
1740	10·0
1820	10·5
1900	11·0
1980	11·5
2060	12·0
2140	12·5
2220	13·0
2300	13·5
2318	14·0
2460	14·5
2540	15·0
2620	15·5
2700	16·0
2770	16·5
2840	17·0
2910	17·5
2980	18·0
3050	18·5
3120	19·0
3190	19·5
3260	20·0
3330	20·5
3400	21·0
3470	21·5
3540	22·0
3600	22·5
3660	23·0
3720	23·5
3780	24·0
3840	24·5
3900	25·0
3960	25·5
4020	26·0
4080	26·5
4130	27·0
4180	27·5
4230	28·0
4280	28·5
4330	29·0
4380	29·5
4430	30·0

RANGE TABLE FOR 16-pr. R.M.L. GUN OF 12 CWT.

Charge, 3lbs. R.L.G., R.L.G.[2] or L.G. powder.

Projectile, common and shrapnel shell.

Range.	Elevation.	Fuze Scale.	Range.	Elevation.	Fuze Scale.
Yards.	° ′		Yards.	° ′	
200	0 0	1	2580	6 6	16
290	0 6	1·5	2650	6 20	16·5
390	0 16	2	2710	6 37	17
480	0 28	2·5	2780	6 50	17·5
570	0 40	3	2840	7 3	18
660	0 52	3·5	2910	7 16	18·5
750	1 4	4	2970	7 29	19
840	1 16	4·5	3040	7 42	19·5
920	1 28	5	3100	7 55	20
1010	1 40	5·5	3160	8 8	20·5
1090	1 52	6	3220	8 21	21
1170	2 4	6·5	3280	8 34	21·5
1250	2 16	7	3330	8 47	22
1330	2 28	7·5	3390	9 0	22·5
1410	2 40	8	3450	9 13	23
1490	2 52	8·5	3510	9 26	23·5
1570	3 4	9	3560	9 39	24
1650	3 16	9·5	3620	9 52	24·5
1720	3 28	10	3680	10 5	25
1800	3 40	10·5	3730	10 18	25·5
1870	3 52	11	3790	10 31	26
1950	4 5	11·5	3840	10 44	26·5
2020	4 18	12	3890	10 57	27
2090	4 31	12·5	3940	11 0	27·5
2160	4 44	13	3990	11 14	28
2230	4 57	13·5	4040	11 28	28·5
2300	5 10	14	4090	11 42	29
2370	5 24	14·5	4140	11 56	29·5
2440	5 38	15	4190	12 10	30
2510	5 52	15·5			

Range Table for 13-pr. R.M.L. Gun.

Based on Practice of 14. 2. 79, 18. 3. 79, 27 and 28. 3. 79.

Weight, 8 cwt.
Charge, 3 lb. 2 oz. R.L.G.[2]
Projectile, common shell or shrapnel, 13 lb. 4 oz.
Muzzle velocity, 1560 f.s.
Jump, 21 minutes.

Range.	Elevation.		Time of Flight.	Angle of Descent. (Approximate.)		Remaining Velocity.	5 minutes' elevation increases or decreases Range by	5 minutes will alter the point of impact, vertically or laterally, at each Range	50 per cent. of rounds fired should fall within			Fuze Scale.	
									Length.	Breadth.	Height.	Range.	Length of Fuze.
yds.	°	′	secs.	°	′	f.s.	yds.	yds.	yds.	yds.	yds.	yds.	
250			0·65	0	23	1482	83·3	0·36	0·45	0·02	0·01	240	1·0
300	0	3	0·78	0	28	1460	62·5	0·43	0·90	0·06	0·02	360	1·5
400	0	11	1·03	0	39	1417	62·5	0·58	2·85	0·19	0·04	480	2·0
500	0	19	1·28	0	51	1376	55·5	0·72	4·70	0·30	0·06	580	2·5
600	0	28	1·53	1	3	1336	55·5	0·87	6·35	0·41	0·09	680	3·0
700	0	37	1·78	1	16	1298	55·5	1·01	7·95	0·51	0·12	780	3·5
800	0	46	2·04	1	30	1262	50·0	1·16	9·45	0·60	0·18	870	4·0
900	0	56	2·30	1	44	1228	50·0	1·31	10·80	0·69	0·26	960	4·5
1000	1	6	2·56	1	59	1195	50·0	1·45	12·15	0·77	0·36	1050	5·0
1100	1	16	2·82	2	14	1164	45·4	1·60	13·50	0·85	0·48	1140	5·5
1200	1	27	3·08	2	30	1135	45·4	1·74	14·70	0·93	0·60	1230	6·0
1300	1	38	3·34	2	46	1108	41·6	1·89	15·90	1·00	0·73	1310	6·5
1400	1	50	3·60	3	3	1083	41·6	3·03	16·95	1·07	0·86	1390	7·0
1500	2	2	3·87	3	21	1060	41·6	2·18	18·00	1·14	1·02	1475	7·5
1600	2	14	4·14	3	40	1039	41·6	2·32	19·05	1·20	1·20	1550	8·0
1700	2	26	4·42	4	0	1020	38·4	2·47	20·10	1·26	1·40	1630	8·5
1800	2	39	4·71	4	20	1003	38·4	2·61	21·15	1·32	1·60	1710	9·0
1900	2	52	5·00	4	40	988	35·7	2·76	22·20	1·38	1·82	1780	9·5
2000	3	6	5·30	5	1	974	35·7	2·91	23·25	1·44	2·05	1850	10·0
2100	3	20	5·60	5	23	961	33·3	3·05	24·15	1·49	2·30	1920	10·5
2200	3	35	5·91	5	46	949	33·3	3·20	25·05	1·54	2·56	1990	11·0
2300	3	50	6·23	6	10	937	31·2	3·34	25·95	1·59	2·84	2060	11·5
2400	4	6	6·56	6	35	925	31·2	3·49	26·85	1·64	3·14	2120	12·0
2500	4	22	6·90	7	1	914	29·4	3·63	27·75	1·69	3·45	2190	12·5
2600	4	39	7·25	7	27	903	29·4	3·78	28·65	1·74	3·78	2250	13·0
2700	4	56	7·61	7	54	892	29·4	3·92	29·55	1·79	4·13	2320	13·5
2800	5	13	7·99	8	22	882	29·4	4·07	30·45	1·84	4·50	2380	14·0
2900	5	30	8·38	8	51	872	29·4	4·21	31·20	1·88	4·90	2440	14·5
3000	5	47	8·78	9	21	862	29·4	4·36	31·95	1·92	5·30	2500	15·0
3100	6	4	9·19	9	52	852	27·7	4·51	32·70	1·96	5·73	2560	15·5
3200	6	22	9·61	10	24	843	27·7	4·65	33·45	2·00	6·18	2620	16·0
3300	6	40	10·03	10	57	834	26·3	4·80	34·20	2·04	6·63	2670	16·5
3400	6	59	10·45	11	31	825	26·3	4·94	34·80	2·08	7·10	2730	17·0
3500	7	18	10·87	12	6	816	25·0	5·09	35·40	2·12	7·60	2780	17·5
3600	7	38	11·30	12	42	807	25·0	5·23	36·00	2·16	8·15	2830	18·0
3700	7	58	11·75	13	18	798	25·0	5·38	36·60	2·19	8·70	2880	18·5
3800	8	18	12·20	13	54	790	23·8	5·52	37·20	2·22	9·25	2930	19·0
3900	8	39	12·65	14	30	782	23·8	5·67	37·80	2·25	9·82	2980	19·5
4000	9	0	13·10	15	6	774	23·8	5·81	38·40	2·28	10·40	3030	20·0
4100	9	21	13·55	15	44	766	23·8	5·96	39·00	2·32		3080	20·5
4200	9	42	14·00	16	24	758	22·7	6·11	39·80	2·36		3130	21·0
4300	10	4	14·45	17	6	751	21·7	6·25	40·60	2·40		3180	21·5
4400	10	27	14·90	17	48	744	20·8	6·40	41·50	2·44		3230	22·0
4500	10	51	15·40	18	30	737	20·8	6·54	42·40	2·48		3280	22·5
4600	11	15	15·90	19	12	730	20·0	6·69	43·30	2·52		3320	23·0
4700	11	40	16·40	19	54	723	19·2	6·83	44·20	2·56		3370	23·5
4800	12	6	16·90	20	39	716	18·5	6·98	45·10	2·60		3410	24·0
4900	12	33	17·40	21	24	709	17·8	7·13	46·00	2·65		3460	24·5
5000	13	1	17·92	22	10	703	17·2	7·27	46·94	2·69		3500	25·0
5100	13	30	18·44	22	57	697	16·6	7·42	47·88	2·74		3540	25·5
5200	14	0	18·96	23	45	691	16·1	7·56	48·88	2·78		3580	26·0
5300	14	31	19·50	24	33	685	15·6	7·71	49·88	2·83		3620	26·5
5400	15	3	20·04	25	21	679	15·1	7·85	50·88	2·87		3660	27·0
5500	15	36	20·60	26	9	673	13·9	8·00	51·90	2·92		3700	27·5
5600	16	12	21·16	27	0	667	12·8	8·14	52·96	2·96		3740	28·0
5700	16	51	21·76	27	51	661	11·9	8·29	54·04	3·01		3780	28·5
5800	17	33	22·36	28	42	655	11·1	8·43	55·14	3·05		3820	29·0
5900	18	18	23·00	29	36	649	10·4	8·58	56·26	3·10		3860	29·5
6000	19	6	23·70	30	42	644	9·8	8·73	57·44	3·15		3900	30·0
6100	19	57	24·44	31	30	639	9·2	8·87	58·65	3·20			

Range Table for 9-pr. R.M.L., S.S. Gun of 8 cwt.

Based on Practice of 23. 10. 73.

Charge 1 lb. 12 oz. R.L.G.^{2} or R.L.G. or L.G.
Projectile, weight, 9¼ lbs.*
Muzzle velocity, 1330 f.s. (about).
Gravimetric density, $\frac{32 \cdot 4}{0 \cdot 856}$ (about).
Mounting, iron slide.
Jump, 15 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an Object 10 feet high, Range must be known within	Velocity.	Time of Flight.	Fuze Scale.	
yards.	° ′	° ′	1 in	yards.	f.s.	secs.	yards.	fuze.
0							305	0·5
100		0 11	312	521	1279	0·23	380	1·0
200	0 5	0 22	156	260	1231	0·47	455	1·5
300	0 16	0 34	101	168	1187	0·72	530	2·0
400	0 27	0 47	73	122	1146	0·96	605	2·5
500	0 39	1 1	56	94	1107	1·24	680	3·0
600	0 51	1 17	45	74	1073	1·51	755	3·5
700	1 4	1 34	37	61	1045	1·80	830	4·0
800	1 17	1 52	31	51	1022	2·09	905	4·5
900	1 30	2 10	26	44	1000	2·39	980	5·0
1000	1 44	2 29	23	38	980	2·69	1050	5·5
1100	1 58	2 49	20	34	960	3·0	1120	6·0
1200	2 13	3 10	18	30	941	3·32	1190	6·5
1300	2 28	3 32	16	27	923	3·64	1255	7·0
1400	2 44	3 55	15	24	906	3·97	1320	7·5
1500	3 1	4 20	13	22	889	4·31	1380	8·0
1600	3 18	4 48	12	20	873	4·65	1440	8·5
1700	3 36	5 18	11	18	858	5·0	1500	9·0
1800	3 55	5 50	9·8	16	843	5·35	1560	9·5
1900	4 15	6 25	8·9	15	828	5·71	1620	10·0
2000	4 36	7 2	8·1	14	814	6·08	1680	10·5
2100	4 58	7 40	7·4	12	800	6·45	1740	11·0
2200	5 21	8 20	6·8	11	787	6·83	1800	11·5
2300	5 45	9 1	6·3	11	774	7·21	1855	12·0
2400	6 9	9 44	5·8	10	761	7·60	1915	12·5
2500	6 34	10 28	5·4	9	749	8·0	1970	13·0
2600	6 59	11 14	5·0	8	737	8·41	2030	13·5
2700	7 25	12 1	4·7	8	725	8·82	2085	14·0
2800	7 52	12 50	4·4	7	713	9·24	2140	14·5
2900	8 20	13 40	4·1	7	701	9·67	2195	15·0
3000	8 49	14 32	3·9	6	690	10·10	2250	15·5
3100	9 19	15 25	3·6	6	678	10·60	2300	16·0
3200	9 50	16 19	3·4	6	667	11·10	2355	16·5
3300	10 21	17 14	3·2	5	656	11·50	2410	17·0
3400	10 53	18 11	3·0	5	645	12·0	2460	17·5
3500	11 26	19 10	2·9	5	634	12·50	2510	18·0
3600	12 0	20 12	2·7	5	624	12·90	2560	18·5
3700	12 35	21 16	2·6	4	614	13·40	2610	19·0
3800	13 11	22 21	2·4	4	604	13·90	2660	19·5
3900	13 48	23 27	2·3	4	594	14·40	2710	20·0
4000	14 26	24 35	2·2	4	584	14·90	2760	20·5
							2805	21·0
							2855	21·5
							2905	22·0
							2950	22·5
							3000	23·0
							3045	23·5
							3095	24·0
							3140	24·5
							3190	25·0
							3235	25·5
							3285	26·C
							3330	26·5
							3375	27·0
							3425	27·5
							3470	28·0
							3515	28·5
							3560	29·0
							3605	29·5
							3650	30·0

Accuracy :—

Range.	50 per cent. of rounds should fall within		
	Length.	Breadth.	Height.
yds.	yds.	yds.	ft.
1000	40	1·2	5
2000	40	3·0	14

* The common shell (filled with P. and F.G.) weighs about 2 oz. less, and the shrapnel about 2 oz. more than this weight.

Range Table for 9-pr. R.M.L., L.S. and S.S. gun of 6 cwt.

Based on Practice of 7. 2. 71.

Charge, 1 lb. 8 oz., R.L.G.[2]
Projectile, 9¼ lb.*
Muzzle velocity, 1200 f.s. (about).
Gravimetric density, $\frac{32 \cdot 4}{0 \cdot 856}$ (about).
Mounting, iron slide.
Jump, 6 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an Object 10 feet high, Range must be known within	Remaining Velocity.	Time of Flight.	Fuze Scale.	
yards.	°	° ′	1 in	yards.	f.s.	secs.	yards.	fuze.
0							300	0·5
100	0 7	0 14	245	409	1158	0·26	370	1·0
200	0 20	0 29	119	198	1118	0·52	445	1·5
300	0 34	0 44	78	130	1084	0·79	520	2·0
400	0 48	1 0	57	95	1054	1·07	595	2·5
							670	3·0
500	1 2	1 17	45	74	1028	1·36	745	3·5
600	1 17	1 35	36	60	1006	1·66	820	4·0
700	1 32	1 53	30	51	985	1·96	890	4·5
800	1 48	2 12	26	43	965	2·27	960	5·0
900	2 4	2 32	23	38	946	2·58	1030	5·5
							1095	6·0
1000	2 20	2 53	20	33	928	2·90	1160	6·5
1100	2 37	3 15	18	29	910	3·23	1225	7·0
1200	2 54	3 38	16	26	893	3·56	1290	7·5
1300	3 12	4 2	14	23	877	3·90	1350	8·0
1400	3 30	4 28	13	21	862	4·24	1410	8·5
							1470	9·0
1500	3 49	4 56	12	19	847	4·59	1530	9·5
1600	4 9	5 26	10	17	832	4·95	1590	10·0
1700	4 30	5 58	9·5	16	818	5·31	1645	10·5
1800	4 51	6 31	8·7	14	804	5·68	1705	11·0
1900	5 13	7 6	8·0	13	791	6·05	1765	11·5
							1810	12·0
2000	5 36	7 44	7·4	12	778	6·43	1870	12·5
2100	6 0	8 24	6·8	11	764	6·82	1925	13·0
2200	6 25	9 6	6·2	10	752	7·21	1985	13·5
2300	6 51	9 50	5·8	10	740	7·61	2030	14·0
2400	7 18	10 37	5·3	9	728	8·02	2085	14·5
							2140	15·0
2500	7 46	11 26	4·9	8	716	8·44	2190	15·5
2600	8 15	12 17	4·6	8	704	8·87	2245	16·0
2700	8 45	13 10	4·3	7	693	9·30	2295	16·5
2800	9 16	14 5	4·0	7	681	9·74	2350	17·0
2900	9 48	15 3	3·7	6	670	10·10	2400	17·5
							2450	18·0
3000	10 21	16 3	3·5	6	659	10·50	2500	18·5
3100	10 55	17 6	3·2	5	648	11·0	2550	19·0
3200	11 30	18 12	3·0	5	637	11·50	2600	19·5
3300	12 6	19 20	2·8	5	627	12·0	2650	20·0
3400	12 42	20 30	2·7	4	617	12·40	2695	20·5
							2745	21·0
3500	13 19	21 43	2·5	4	607	12·90	27[illegible]0	21·5
3600							2840	22·0
3700							2885	22·5
3800							2935	23·0
3900							2980	23·5
							3030	24·0
4000							3075	24·5
							3120	25·0
							3165	25·5
							3210	26·0
							3260	26·5
							3305	27·0
							3350	27·5
							3400	28·0
							3445	28·5
							3490	29·0
							3535	29·5
							3580	30·0

* The common shell (filled with P. and F.G.) weighs about 2 oz. less, and the shrapnel shell about 2 oz. more than this weight.

Accuracy.—The accuracy is very similar to that of the 9-pr. of 8 cwt.

(C.O.)

Range Table for 2·5-inch steel R.M.L. Gun.

Based on Practice of 19 and 20. 12. 78.

Charge, 1 lb. 8 oz. R.L.G.[2]; gravimetric density, $\frac{36\cdot0}{0\cdot770}$.
Projectile, common shell or shrapnel, weight 7 lb.
Muzzle velocity, 1440 f.s.
Jump, 10½ minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	Time of Flight.	Fuse Scale. Small.	Fuse Scale. Medium.	50 per cent. should fall within Length.	50 per cent. should fall within Breadth.	50 per cent. should fall within Height.
yds.	° ′	° ′	f.s.	yards.	yards.	secs.					
100			1384						20	0·1	0·1
200	0 7	0 20	1328	78·9	0·29	0·51			20	0·1	0·1
300	0 16	0 31	1279	71·0	0·43	0·75			20	0·1	0·2
400	0 25	0 43	1233	61·6	0·58	0·99	0·56		20	0·2	0·2
500	0 35	0 55	1190	59·5	0·72	1·24	0·71		20	0·3	0·3
600	0 47	1 8	1150	57·5	0·87	1·49	0·86		20	0·3	0·4
700	0 58	1 22	1114	55·6	1·01	1·74	1·01		19	0·4	0·5
800	1 9	1 37	1080	49·1	1·16	1·99	1·16		19	0·4	0·5
900	1 21	1 53	1054	43·4	1·31	2·25	1·31		19	0·5	0·6
1000	1 33	2 10	1028	42·5	1·45	2·51	1·46	0·67	19	0·6	0·7
1100	1 46	2 28	1006	38·4	1·60	2·79	1·61	1·00	19	0·6	0·8
1200	2 0	2 47	988	35·9	1 74	3·09	1·77	1·17	18	0·7	0·9
1300	2 15	3 7	970	32·4	1·89	3·39	1·92	1·33	18	0·8	1·0
1400	2 31	3 28	953	31·4	2·03	3·71	2·08	1·49	18	0·9	1·1
1500	2 47	3 51	936	30·5	2·18	4·03	4·24	1·65	18	0·9	1·2
1600	3 3	4 14	919	29·6	2·32	4·36	2·40	1·80	18	1·0	1·3
1700	3 19	4 38	902	28·7	2·47	4·70	2·56	1·95	18	1·1	1·4
1800	3 35	5 3	885	27·8	2·61	5·04	2·73	2·10	18	1·2	1·5
1900	3 52	5 28	868	26·9	2·76	5·39	2·89	2·26	18	1·3	1·7
2000	4 9	5 54	852	26·0	2·91	5·74	3·06	2·41	18	1·3	1·8
2100	4 26	6 20	837	25·1	3·05	6·10	3·23	2·57	18	1·4	1·9
2200	4 44	6 46	823	24·2	3·21	6·47	3·41	2·72	18	1·5	2·1
2300	5 2	7 13	809	23·4	3·34	6·85	3·59	2·88	18	1·7	2·2
2400	5 20	7 41	796	22·6	3·49	7·23	3·77	3·03	18	1·8	2·4
2500	5 38	8 10	783	21·8	3·63	7·62	3·96	3·20	18	1·9	2·5
2600	5 57	8 40	770	21·0	3·78	8·01		3·36	18	2·0	2·7
2700	6 17	9 11	758	20·2	3·92	8·40		3·54	18	2·2	2·9
2800	6 37	9 42	746	19·4	4·07	8·80		3·71	18	2·3	3·1
2900	6 58	10 14	735	18·6	4·21	9·20		3·89	18	2·5	3·3
3000	7 19	10 46	724	17·8	4·36	9·60		4·06	18	2·6	3·5
3100	7 40	11 20	713	17·1	4·51	10·02		4·24	19	2·8	3·7
3200	8 1	11 54	702	16·4	4·65	10·44		4·42	19	2·9	4·0
3300	8 23	12 30	691	15·7	4·80	10·87		4·61	19	3·1	4·2
3400	8 45	13 6	680	15·1	4·94	11·31		4·80	19	3·3	4·5
3500	9 7	14 43	669	14·6	5·09	11·75			19	3·4	4·7
3600	9 30	14 20	658	14·1	5·23	12·20			20	3·6	5·1
3700	9 54	14 59	647	13·5	5·38	12·66			20	3·8	5·4
3800	10 18	15 39	637	13·0	5·52	13·12			20	4·0	5·8
3900	10 43	16 21	627	12·5	5·67	13·59			20	4·2	6·2
4000	11 7	17 4	617	12·0	5·81	14·07			20	4·4	6·6

Range Table for 7-pr. R.M.L. Gun of 200 lbs.

Based on Calculation, checked by Practice of 25. 8. 76.

Charge, 12 oz. F.O. or R.F.G.*
Projectile, weight 7¼ lbs.*
Muzzle velocity, 950 f.s. (about).
Jump (estimated at), 6 minutes.

Range.	Elevation.
Yards.	° ′
0	
100	0 14
200	0 34
300	0 54
400	1 14
500	1 35
600	1 56
700	2 17
800	2 39
900	3 1
1000	3 23
1100	3 46
1200	4 9
1300	4 33
1400	4 58
1500	5 24
1600	5 51
1700	6 19
1800	6 49
1900	7 20
2000	7 52
2100	8 25
2200	9 0

Fuze Scale for 15 Seconds M.L. Wood Time Fuze.	
Yards.	Tenths.
350	1·0
420	1·5
485	2·0
550	2·5
615	3·0
680	3·5
740	4·0
800	4·5
860	5·0
920	5·5
980	6·0
1040	6·5
1100	7·0
1160	7·5
1220	8·0
1275	8·5
1330	9·0
1385	9·5
1440	10·0
1495	10·5
1550	11·0
1605	11·5
1660	12·0
1710	12·5
1760	13·0
1810	13·5
1860	14·0
1910	14·5
1960	15·0
2010	15·5

Range.	Elevation.
Yards.	° ′
2300	9 36
2400	10 13
2500	10 51
2600	11 31
2700	12 13
2800	12 56
2900	13 40
3000	14 25

Fuze Scale for 15 Seconds M.L. Wood Time Fuze.	
Yards.	Tenths.
2060	16·0
2105	16·5
2150	17·0
2195	17·5
2240	18·0
2285	18·5
2330	19·0
2375	19·5
2420	20·0
2465	20·5
2510	21·0
2555	21·5
2600	22·0
2640	22·5
2680	23·0
2720	23·5
2760	24·0
2800	24·5
2840	25·0
2880	25·5
2915	26·0
2950	26·5
2985	27·0
3020	27·5
3055	28·0
3080	28·5
3115	29·0
3150	29·5
3185	30·0

* The practice was carried out with F.G. powder and 7¼ lbs. shell, hence the necessity for calculation.

RANGE TABLE FOR 7-PR. R.M.L. GUN OF 200 LBS. (*Steel.*)

Charge, 4 oz. F.G. powder.

Projectile, double shell.

Range.	Elevation.	Fuze Scale.	Range.	Elevation.	Fuze Scale.
Yards.	° ′		Yards.	° ′	
700	8 12	8·5	1420	21 23	20
730	8 44	9	1450	21 58	20·5
760	9 16	9·5	1470	22 33	21
800	9 48	10	1500	23 10	21·5
830	10 20	10·5	1520	23 49	22
860	10 52	11	1550	24 28	22·5
900	11 24	11·5	1570	25 7	23
930	11 56	12	1600	25 48	23·5
960	12 28	12·5	1620	26 33	24
1000	13 0	13	1650	27 18	24·5
1030	13 36	13·5	1670	28 3	25
1060	14 12	14	1700	28 50	25·5
1100	14 48	14·5	1720	29 33	26
1130	15 24	15	1740	30 16	26·5
1160	16 0	15·5	1760	30 59	27
1200	16 36	16	1780	31 42	27·5
1230	17 16	16·5	1800	32 46	28
1260	17 56	17	1820	33 6	28·5
1300	18 38	17·5	1840	33 46	29
1320	19 10	18	1860	34 26	29·5
1350	19 42	18·5	1880	35 6	30
1370	20 14	19			
1400	20 48	19·5			

RANGE TABLE FOR 7-PR. R.M.L. GUN OF 150 LBS.

Charge, 6 oz. F.G. powder.

Projectile, common shell.

Range.	Elevation.	Fuze Scale.	Range.	Elevation.	Fuze Scale.
Yards.	° ′		Yards.	° ′	
130	0 30	1	1440	9 43	13·5
190	0 49	1·5	1480	10 16	14
250	1 8	2	1520	10 30	14·5
310	1 27	2·5	1570	11 0	15
370	1 46	3	1610	11 27	15·5
430	2 5	3·5	1650	11 54	16
480	2 21	4	1690	12 21	16·5
540	2 43	4·5	1730	12 48	17
600	3 5	5	1770	13 15	17·5
650	3 25	5·5	1800	13 37	18
700	3 45	6	1840	14 4	18·5
750	4 5	6·5	1870	14 28	19
810	4 30	7	1910	14 55	19·5
870	4 55	7·5	1950	15 22	20
920	5 17	8	1980	15 47	20·5
970	5 39	8·5	2010	16 12	21
1020	6 2	9	2050	16 45	21·5
1070	6 25	9·5	2080	17 15	22
1120	6 49	10			
1170	7 13	10·5			
1220	7 37	11			
1260	7 58	11·5			
1310	8 28	12			
1350	8 50	12·5			
1400	9 20	13			

Range Table for 7-pr. R.M.L. Bronze Gun of 200 lbs.

Charge, 8 oz. F.G. or R.F.G. Powder.
Projectile, Common Shell.

Range.	Elevation.		Time of Flight.	Fuze Scale.	Range.	Elevation.		Time of Flight.	Fuze Scale.
Yards.	°	′	Secs.	Inches.	Yards.	°	′	Secs.	Inches.
100	0	13	0·36	0·05	2900	18	27	15·30	2·75
200	0	29	0·76	0·15	3000	19	32	16·04	2·85
300	0	47	1·17	0·20	3100	20	39	16·80	3·00
400	1	6	1·58	0·30	3200				
500	1	26	2·00	0·35	3300				
600	1	48	2·42	0·45	3400				
700	2	11	2·85	0·50	3500				
800	2	36	3·30	0·60	3600				
900	3	3	3·76	0·65	3700				
1000	3	31	4·23	0·75	3800				
1100	4	0	4·70	0·85	3900				
1200	4	31	5·18	0·95	4000				
1300	5	5	5·67	1·00					
1400	5	41	6·17	1·10					
1500	6	19	6·68	1·20					
1600	6	59	7·20	1·30					
1700	7	41	7·74	1·40					
1800	8	25	8·30	1·50					
1900	9	11	8·86	1·60					
2000	9	59	9·43	1·70					
2100	10	49	10·02	1·80					
2200	11	40	10·63	1·90					
2300	12	33	11·26	2·00					
2400	13	27	11·90	2·15					
2500	14	23	12·54	2·25					
2600	15	21	13·20	2·35					
2700	16	21	13·88	2·50					
2800	17	23	14·58	2·60					

Range Table for 8-inch R.M.L. Howitzer of 70 cwt.

Based on Practice of July, September, and December, 1879.

Charge, 11¼ lb. R.L.G.[2]

Projectiles, common, and battering shells, fitted with rotating gas-checks, weight, 180 lbs.

Muzzle velocity, 956 f.s.

Range.	Drift, right.	Elevation.	Deflection, left.	Angle of Descent.	Remaining Velocity.	Five minutes' elevation increases or decreases the Range by	Five minutes will alter point of impact vertically or laterally at each Range	50 per cent. of rounds, should fall within			Time of Flight.*
								Length.	Breadth.	Height.	
yds.	yds.	° ′	° ′	° ′	f.s.	yds.	yds.	yds.	yds.	yds.	secs.
300		0 44			935	25·0	0·43				
400		1 4			928	25·0	0·58				
500	0·3	1 24	0 2	1 38	921	25·0	0·72	7·0	0·14	0·20	1·6
600	0·4	1 44	0 3	1 56	914	25·0	0·87	8·4	0·18	0·31	1·9
700	0·6	2 4	0 3	2 16	907	25·0	1·01	9·8	0·21	0·43	2·3
800	0·8	2 24	0 3	2 36	900	25·0	1·16	11·2	0·25	0·55	2·6
900	1·0	2 44	0 4	2 56	894	25·0	1·31	12·5	0·28	0·67	3·0
1000	1·3	3 4	0 5	3 17	888	25·0	1·45	13·8	0·32	0·79	3·3
1100	1·6	3 24	0 5	3 38	882	25·0	1·60	15·1	0·36	1·00	3·7
1200	1·9	3 44	0 6	4 0	876	25·0	1·74	16·4	0·40	1·21	4·0
1300	2·3	4 4	0 7	4 24	870	25·0	1·89	17·7	0·44	1·42	4·4
1400	2·8	4 24	0 7	4 48	864	23·8	2·03	18·9	0·48	1·63	4·7
1500	3·3	4 45	0 8	5 12	858	23·8	2·18	20·1	0·52	1·84	5·1
1600	3·8	5 6	0 9	5 36	852	23·8	2·32	21·3	0·56	2·14	5·4
1700	4·4	5 27	0 10	6 0	846	23·8	2·47	22·5	0·60	2·44	5·8
1800	5·0	5 48	0 10	6 25	840	23·8	2·61	23·7	0·64	2·74	6·1
1900	5·6	6 9	0 10	6 50	834	23·8	2·76	24·9	0·68	3·05	6·5
2000	6·3	6 30	0 11	7 16	829	23·8	2·91	26·1	0·72	3·36	6·8
2100	7·1	6 51	0 11	7 44	824	23·8	3·05	27·3	0·77	3·78	7·2
2200	7·9	7 12	0 12	8 12	819	23·8	3·20	28·5	0·82	4·21	7·5
2300	8·7	7 33	0 13	8 42	814	23·8	3·34	29·7	0·87	4·64	7·9
2400	9·5	7 54	0 13	9 12	809	22·7	3·49	30·9	0·92	5·07	8·2
2500	10·4	8 16	0 14	9 42	804	22·7	3·63	32·1	0·98	5·50	8·6
2600	11·3	8 38	0 15	10 12	799	21·7	3·78	33·3	1·04	6·08	9·0
2700	12·3	9 1	0 16	10 42	794	21·7	3·92	34·5	1·10	6·66	9·4
2800	13·4	9 24	0 16	11 14	789	20·8	4·07	35·7	1·17	7·25	9·8
2900	14·5	9 48	0 17	11 48	784	20·8	4·21	36·9	1·25	7·84	10·2
3000	15·7	10 12	0 18	12 24	779	19·2	4·36	38·0	1·33	8·43	10·6
3100	17·0	10 38	0 19	13 0	775	19·2	4·51	39·1	1·41	9·14	11·0
3200	18·5	11 4	0 20	13 36	771	19·2	4·65	40·2	1·49	9·85	11·4
3300	20·1	11 30	0 21	14 12	767	19·2	4·80	41·3	1·57	10·56	11·8
3400	21·8	11 56	0 22	14 48	763	17·8	4·94	42·4	1·66	11·28	12·2
3500	23·6	12 24	0 23	15 26	759	17·8	5·09	43·5	1·75	12·00	12·6
3600	25·5	12 52	0 24	16 6	755	17·8	5·23	44·6	1·85	12·96	13·0
3700	27·5	13 20	0 25	16 48	751	17·8	5·38	45·7	2·00	13·92	13·4
3800	29·6	13 48	0 26	17 13	747	16·6	5·52	46·7	2·15	14·88	13·8
3900	31·8	14 18	0 28	18 14	745	16·6	5·67	47·7	2·30	15·84	14·2
4000	34·0	14 48	0 29	19 0	739	16·6	5·81	48·6	2·45	16·80	14·7
4100	36·4	15 18	0 30	19 48	735	16·6	5·96	49·5	2·60	17·96	15·2
4200	39·0	15 48	0 31	20 36	731	16·6	6·11	50·4	2·80	19·12	15·7
4300	42·0	16 18	0 33	21 24	727	15·6	6·25	51·3	3·00	20·28	16·2
4400	45·2	16 50	0 35	22 12	723	15·6	6·40	52·1	3·20		16·7
4500	48·5	17 22	0 37	23 2	720	14·7	6·54	52·9	3·40		17·2
4600	51·5	17 56	0 38	23 54	717	14·7	6·69	53·7	3·35		17·7
4700	55·0	18 30	0 40	24 48	715	13·9	6·84	54·5	3·90		18·2
4800	59·0	19 6	0 42	25 42	713	13·9	6·98	55·3	4·15		18·7
4900	63·0	19 42	0 44	26 36	711	13·9	7·13	56·1	4·40		19·2
5000	67·0	20 18	0 46	27 36	709	13·1	7·27	56·9	4·65		19·7
5100	72·0	20 56	0 48	28 40	708	12·5	7·42	57·7	4·92		20·2
5200	77·0	21 36	0 50	29 46	707	11·9	7·56	58·5	5·19		20·7
5300	82·0	22 18	0 53	30 54	706	11·9	7·71	59·3	5·46		21·3
5400	87·5	23 0	0 55	32 7	705	11·3	7·85	60·1	5·73		21·9
5500	93·0	23 44	0 58	33 24	704	11·3	8·00	60·9	6·00		22·5
5600	99·0	24 28	1 0	34 44	703	11·3	8·14	61·6	6·27		23·1
5700	105·0	25 12	1 3	36 4	704	10·4	8·29	62·3	6·54		23·7
5800	111·5	26 0	1 6	37 24	705	10·0	8·43	63·0	6·82		24·3
5900	118·0	26 50	1 8	38 48	706	9·6	8·58	63·7	7·10		25·0
6000	124·5	27 42	1 11	40 12	707	9·2	8·73	64·4	7·40		25·7
6100	131·0	28 36	1 13	41 36	708	9·2	8·87	65·1	7·70		26·4
6200	137·5	29 30	1 16	43 0	709	9·2	9·02	65·8	8·00		27·1
6300	144·0	30 24	1 18	44 24	710	8·9	9·16	66·4	8·35		27·9

Range Tables for 8-inch R.M.L. Howitzer of 70 cwt.

Charge, 7 lb. R.L.G.[3] Muzzle velocity, 715 f.s.

Range.	Drift, right.	Elevation.	Deflection, left.	Angle of Descent.	Remaining Velocity.	Five minutes' elevation increases or decreases the Range by	Five minutes will alter point of impact vertically or laterally at each Range	50 per cent. of rounds should fall within		
								Length.	Breadth.	Height.	Time of Flight.
yards.	yards.	° ′	° ′	° ′	f.s.	yards.	yards.	yards.	yards.	yards.	secs.
300		1 20			700	13·9	0·43				
400		1 56			695	13·9	0·58				
500	0·8	2 32	0 6	3 0	690	13·9	0·72	5·4	0·27	0·29	1·8
600	1·2	3 8	0 7	3 36	686	13·1	0·87	6·4	0·33	0·46	2·2
700	1·7	3 46	0 8	4 12	682	13·1	1·01	7·4	0·39	0·63	2·6
800	2·3	4 24	0 10	4 54	678	13·1	1·16	8·4	0·45	0·80	3·0
900	3·0	5 2	0 11	5 36	674	13·1	1·31	9·4	0·51	0·98	3·4
1000	3·8	5 40	0 13	6 18	670	13·1	1·45	10·4	0·57	1·16	3·8
1110	4·7	6 18	0 15	7 0	666	13·1	1·60	11·4	0·63	1·46	4·2
1200	5·7	6 56	0 16	7 42	662	13·1	1·74	12·4	0·69	1·77	4·6
1300	6·8	7 34	0 18	8 24	658	13·1	1·89	13·4	0·76	2·08	5·1
1400	8·0	8 12	0 19	9 9	654	12·5	2·03	14·4	0·82	2·39	5·6
1500	9·2	8 52	0 21	9 54	650	12·5	2·18	15·4	0·88	2·70	6·1
1600	10·5	9 32	0 22	10 42	646	12·5	2·32	16·4	0·94	3·16	6·6
1700	11·9	10 12	0 24	11 30	642	12·5	2·47	17·3	1·01	3·62	7·1
1800	13·3	10 52	0 25	12 18	638	12·5	2·61	18·2	1·08	4·08	7·6
1900	14·8	11 32	0 27	13 6	634	12·5	2·76	19·1	1·15	4·54	8·1
2000	16·4	12 12	0 28	14 0	631	12·5	2·91	20·0	1·22	5·00	8·6
2100	18·1	12 52	0 30	14 54	628	12·5	3·05	20·9	1·30	5·66	9·1
2200	19·8	13 32	0 31	15 48	625	12·5	3·20	21·8	1·38	6·32	9·6
2300	21·6	14 12	0 33	16 42	622	11·3	3·34	22·7	1·46	6·98	10·2
2400	23·5	14 56	0 34	17 42	619	10·8	3·49	23·6	1·54	7·65	10·8
2500	25·5	15 42	0 35	18 42	616	10·4	3·63	24·5	1·63	8·32	11·4
2600	27·5	16 30	0 36	19 42	613	10·4	3·78	25·4	1·72	9·08	12·0
2700	29·7	17 18	0 37	20 42	610	10·4	3·92	26·3	1·81	9·84	12·6
2800	32·0	18 6	0 39	21 48	607	9·2	4·07	27·2	1·91	10·60	13·3
2900	34·3	19 0	0 40	22 54	604	9·2	4·21	28·0	2·02	11·36	14·0
3000	37·0	19 54	0 42	24 6	601	8·9	4·36	28·8	2·13	12·13	14·7
3100	39·7	20 50	0 44	25 18	598	8·3	4·51	29·6	2·24	13·62	15·4
3200	42·5	21 50	0 45	26 36	595	7·8	4·65	30·4	2·37	15·11	16·1
3300	45·5	22 54	0 47	27 57	592	7·5	4·80	31·2	2·50	16·60	16·8
3400	48·7	24 0	0 49	29 18	590	6·9	4·94	32·0	2·65	18·10	17·5
3500	52·0	25 12	0 51	30 48	588	6·9	5·09	32·8	2·80	19·60	18·3
3600	56·0	26 54	0 53	32 24	587	6·7	5·23	33·6	2·95		19·1
3700	60·0	27 38	0 55	34 12	588	6·0	5·38	34·4	3·12		19·9
3800	64·0	29 0	0 58	36 12	589	5·9	5·52	35·2	3·32		20·7
3900	68·5	30 24	1 0	38 30	590	5·8	5·67	36·0	3·53		21·5

Charge, 3½ lb. R.L.G.[3] Muzzle velocity, 473 f.s.

300		3 12			464	6·0	0·43				
400		4 30			460	6·0	0·58				
500	2·2	5 50	0 15	6 54	457	6·0	0·72	8·2	0·55	1·0	3·2
600	3·0	7 12	0 17	8 18	454	5·8	0·87	10·1	0·67	1·5	3·9
700	3·9	8 38	0 19	9 42	451	5·7	1·01	11·9	0·80	2·0	4·6
800	5·1	10 6	0 22	11 6	448	5·5	1·16	13·8	0·93	2·7	5·3
900	6·3	11 36	0 24	12 30	445	5·3	1·31	15·7	1·06	3·5	6·0
1000	7·7	13 10	0 26	14 6	442	5·1	1·45	17·6	1·20	4·4	6·8
1100	9·4	14 48	0 29	15 48	440	4·7	1·60	19·6	1·35	5·5	7·6
1200	11·4	16 33	0 33	17 30	438	4·6	1·74	21·7	1·50	6·9	8·4
1300	13·5	18 21	0 36	19 18	436	4·4	2·89	23·8	1·66	8·4	9·2
1400	16·0	20 15	0 39	21 18	434	4·2	2·03	25·9	1·83	10·1	10·0
1500	19·0	22 15	0 43	23 30	432	4·0	2·18	28·1	2·00	12·3	10·9
1600	22·3	24 21	0 48	26 0	433	3·6	2·32	30·4	2·18	14·9	11·8
1700	27·0	26 38	0 54	28 42	434	3·1	2·47	32·9	2·37	18·0	12·8
1800	34·0	29 18	1 5	32 6	435	2·7	2·61	35·4	2·57	22·4	13·8
1900	42·2	32 24	1 16	37 37	436	2·1	2·76	38·2	2·80	29·4	14·9

Range Table for 8-inch R.M.L. Howitzer of 46 cwt.

Mean Elevation due to each 100 yards of Range, by Interpolation.

Charge, 5 lb. R.L.G. or L.G.

Range.	Drift.	Elevation.	Deflection.	Value of 5'.		Time of Flight.
				Elevation in Range.	Deflections.	
yds.	yds.	° ′	° ′	yds.	yds.	secs.
400	3·5	5 40	0 31	7·1	0·56	2·9
500	5·0	7 0	0 36	6·3	0·70	3·5
600	6·5	8 20	0 39	6·3	0·83	4·2
700	8·0	9 45	0 41	6·0	0·97	4·9
800	10·0	11 10	0 45	6·0	1·11	5·6
900	12·0	12 45	0 48	5·3	1·25	6·3
1000	14·3	14 30	0 51	4·8	1·39	7·1
1100	16·8	16 15	0 55	4·8	1·53	8·0
1200	20·0	18 25	1 0	3·8	1·67	9·0
1300	23·5	20 35	1 5	3·8	1·80	10·0
1400	27·5	23 0	1 10	3·5	1·94	11·0
1500	32·5	26 0	1 17	2·8	2·08	12·2
1600	39·5	29 30	1 28	2·4	2·22	13·7
1700	48·0	33 30	1 41	2·1	2·36	15·3
1800	61·0	39 0	2 2	1·5	2·50	17·4

Charge, 10 lb. R.L.G or L.G.

Projectile, common shell and gas-check, 185 lb.

400	0·9	2 0	0 8	14·3	0·56	1·7
500	1·8	2 35	0 13	14·3	0·70	2·1
600	2·8	3 10	0 17	14·3	0·83	2·6
700	4·0	3 50	0 21	12·5	0·97	3·1
800	5·3	4 30	0 24	12·5	1·11	3·6
900	6·6	5 10	0 26	12·5	1·25	4·1
1000	8·0	5 50	0 29	12·5	1·39	4·6
1100	9·5	6 30	0 31	12·5	1·53	5·1
1200	11·0	7 10	0 33	12·5	1·67	5·6
1300	12·7	7 50	0 35	12·5	1·80	6·1
1400	14·5	8 35	0 37	11·1	1·94	6·6
1500	16·4	9 20	0 39	11·1	2·08	7·1
1600	18·5	10 5	0 42	11·1	2·22	7·6
1700	20·7	10 55	0 44	11·1	2·36	8·1
1800	22·9	11 35	0 46	11·1	2·50	8·6
1900	25·2	12 20	0 48	11·1	2·64	9·1
2000	27·6	13 5	0 50	11·1	2·78	9·6
2100	30·6	13 55	0 52	10·0	2·92	10·2
2200	33·7	14 45	0 55	10·0	3·06	10·8
2300	37·3	15 35	0 58	10·0	3·20	11·3
2400	41·5	16 20	1 2	9·1	3·34	11·9
2500	45·5	17 25	1 6	9·1	3·48	12·5
2600	51·0	18 25	1 11	8·3	3·61	13·1
2700	57·0	19 25	1 16	8·3	3·75	13·7
2800	64·0	20 30	1 23	8·0	3·89	14·4
2900	72·0	21 40	1 29	7·1	4·03	15·2
3000	81·0	22 50	1 37	7·1	4·17	16·0
3100	90·0	24 0	1 45	7·1	4·31	16·7
3200	100·0	25 15	1 53	6·6	4·44	17·4
3300	111·0	26 45	2 1	5·5	4·58	18·3
3400	123·0	28 25	2 10	5·0	4·72	19·3
3500	137·0	30 15	2 21	4·5	4·86	20·4
3600	154·0	32 25	2 33	3·8	5·00	21·6
3700	176·0	35 0	2 51	3·2	5·13	23·1
3800	204·0	38 15	3 11	2·6	5·27	24·9

Range Table for 6·6-inch R.M.L. Howitzer of 36 cwt.

Projectiles, common and shrapnel shells, fitted with rotating gas-checks; weight, 100 lbs.

Charge, 5 lb. R.L.G.^{2} powder.
Muzzle velocity, 839 f.s.

Range.	Drift, right.	Elevation.		Deflection, left.		Angle of Descent.		Remaining Velocity.	Five minutes' elevation increases or decreases the Range by	Five minutes will alter point of impact vertically or laterally at each Range	50 per cent. of rounds should fall within			Time of Flight.
											Length.	Breadth.	Height.	
yds.	yds.	°	′	°	′	°	′	f.s.	yds.	yds.	yds.	yds.	yds.	secs.
400	0·05	0	58	0	0·4	1	40	811	17·9	0·58	6·1	0·08	0·18	1·4
500	0·2	1	26	0	1	2	8	805	17·9	0·72	7·6	0·10	0·28	1·7
600	0·4	1	54	0	2	2	36	799	17·9	0·87	9·1	0·12	0·41	2·0
700	0·6	2	22	0	2	3	4	793	17·9	1·01	10·5	0·16	0·56	2·4
800	0·8	2	50	0	3	3	32	787	17·9	1·16	11·9	0·20	0·74	2·8
900	1·0	3	18	0	4	4	1	781	17·9	1·30	13·3	0·25	0·93	3·2
1000	1·2	3	46	0	4	4	30	775	17·9	1·45	14·6	0·30	1·15	3·6
1100	1·5	4	14	0	5	5	0	769	17·9	1·60	15·9	0·35	1·39	4·0
1200	1·8	4	42	0	5	5	30	763	17·9	1·74	17·2	0·40	1·66	4·4
1300	2·1	5	10	0	6	6	3	757	17·9	1·89	18·5	0·50	1·97	4·8
1400	2·4	5	38	0	6	6	36	751	17·9	2·03	19·8	0·60	2·30	5·2
1500	2·8	6	6	0	6	7	12	745	17·9	2·18	21·1	0·70	2·70	5·6
1600	3·2	6	34	0	7	7	48	739	17·9	2·32	22·4	0·80	3·10	6·0
1700	3·6	7	2	0	7	8	24	734	17·9	2·47	23·7	0·90	3·50	6·4
1800	4·0	7	30	0	8	9	0	729	17·9	2·61	25·0	1·00	4·00	6·8
1900	4·4	7	58	0	8	9	36	724	17·9	2·76	26·3	1·20	4·50	7·2
2000	4·8	8	26	0	8	10	18	719	17·9	2·91	27·6	1·40	5·05	7·6
2100	5·3	8	54	0	9	11	0	714	16·7	3·05	28·9	1·60	5·65	8·0
2200	5·8	9	24	0	9	11	42	709	16·7	3·20	30·2	1·80	6·30	8·4
2300	6·3	9	54	0	9	12	24	704	16·7	3·34	31·5	2·00	6·98	8·8
2400	6·8	10	24	0	10	13	12	700	16·7	3·49	32·8	2·30	7·75	9·2
2500	7·3	10	54	0	10	14	0	696	16·7	3·63	34·1	2·60	8·60	9·6
2600	7·9	11	24	0	10	14	48	692	16·7	3·78	35·4	2·90	9·50	10·0
2700	8·5	11	54	0	11	15	36	688	16·7	3·92	36·7	3·25	10·40	10·4
2800	9·2	12	24	0	11	16	24	684	16·7	4·07	38·0	3·60	11·30	10·8
2900	10·0	12	54	0	12	17	18	680	16·7	4·21	39·2	3·95	12·30	11·3
3000	10·8	13	24	0	12	18	12	676	13·9	4·36	40·4	4·30	13·40	11·8
3100	11·8	14	0	0	13	19	6	672	13·9	4·51	41·6	4·70	14·50	12·3
3200	12·8	14	36	0	14	20	0	668	13·9	4·65	42·8	5·20	15·70	12·8
3300	14·0	15	12	0	15	20	54	664	13·9	4·80	44·0	5·70	16·90	13·3
3400	15·5	15	48	0	16	21	48	660	13·9	4·94	45·2	6·20	18·20	13·8
3500	17·2	16	24	0	17	22	48	656	13·9	5·09	46·4	6·80	19·60	14·3
3600	19·2	17	0	0	18	23	48	653	13·9	5·23	47·6	7·40		14·8
3700	21·5	17	36	0	20	24	48	650	12·5	5·38	48·8	8·00		15·3
3800	24·0	18	16	0	22	25	48	647	11·9	5·52	50·0	8·70		15·8
3900	26·8	18	58	0	24	26	54	644	11·9	5·67	51·2	9·40		16·4
4000	29·9	19	40	0	26	28	0	642	11·4	5·81	52·4	10·20		17·0
4100	33·3	20	24	0	28	29	12	640	10·4	5·96	53·6	11·10		17·6
4200	37·0	21	12	0	30	30	24	638	10·4	6·11	54·8	12·00		18·2
4300	41·2	22	0	0	33	31	42	636	10·4	6·25	56·0	13·00		18·8
4400	45·8	22	48	0	36	33	6	635	9·3	6·40	57·1	14·00		19·5
4500	50·8	23	42	0	39	34	30	634	9·3	6·54	58·2	15·30		20·2
4600	56·2	24	36	0	42	35	54	635	8·3	6·69	59·3	16·60		20·9
4700	62·0	25	36	0	45	37	24	637	8·3	6·84	60·4	18·10		21·6
4800	68·5	26	36	0	49	39	0	640	7·6	6·98	61·5	19·16		22·4
4900	75·5	27	42	0	53	40	36	643	7·0	7·13	62·6	21·20		23·2
5000	83·5	28	54	0	57	42	24	646	6·4	7·27	63·6	23·20		24·1
5100	93·0	30	12	1	3	44	18	649	5·6	7·42	64·6	25·40		25·1
5200	104·0	31	42	1	7	46	24	652	4·9	7·56	65·6	27·90		26·1
5300	116·5	33	24	1	16	48	54	655	4·0	7·71	66·6	31·00		27·3
5400	130·0	35	30	1	23	52	3	658	3·1	7·85	67·6	35·40		28·6

Range Tables for the 6·6-inch R.M.L. Howitzer of 36 cwt.

Charge, 3 lb. R.L.G.[2] powder. Muzzle velocity, 619 f.s.

Range.	Drift, right.	Elevation.		Deflection, left.		Angle of Descent.		Remaining Velocity.	Five minutes' elevation increases or decreases the Range by	Five minutes will alter point of impact vertically or laterally at each Range	50 per cent. of rounds should fall within: Length.	Breadth.	Height.	Time of Flight.
yds.	yds.	°	′	°	′	°	′	f.s.	yds.	yds.	yds.	yds.	yds.	secs.
400	1·0	2	36	0	8	3	0	599	10·9	0·58	3·1	0·10	0·16	1·9
500	1·2	3	22	0	8	3	48	594	10·9	0·72	3·9	0·16	0·26	2·4
600	1·5	4	8	0	9	4	36	589	10·9	0·87	4·7	0·22	0·38	2·9
700	1·9	4	54	0	9	5	24	584	10·6	1·01	5·5	0·28	0·52	3·4
800	2·4	5	41	0	10	6	18	579	10·6	1·16	6·3	0·40	0·70	3·9
900	3·0	6	28	0	11	7	12	574	10·4	1·31	7·1	0·55	0·90	4·4
1000	3·7	7	16	0	13	8	6	569	10·3	1·45	7·9	0·70	1·15	4·9
1100	4·5	8	5	0	14	9	0	564	10·2	1·60	8·6	0·85	1·37	5·4
1200	5·4	8	54	0	16	10	0	560	10·0	1·74	9·3	1·00	1·64	5·9
1300	6·3	9	44	0	17	11	0	556	9·6	1·89	10·0	1·20	1·96	6·5
1400	7·3	10	36	0	18	12	0	553	9·3	2·03	10·7	1·40	2·28	7·1
1500	8·5	11	30	0	20	13	6	550	9·3	2·18	11·4	1·60	2·65	7·7
1600	10·0	12	24	0	22	14	12	547	9·3	2·32	12·1	1·90	3·06	8·3
1700	11·7	13	18	0	24	15	24	544	9·3	2·47	12·8	2·20	3·50	8·9
1800	13·5	14	12	0	26	16	36	541	8·3	2·61	13·5	2·50	4·02	9·5
1900	15·5	15	12	0	28	17	54	538	8·3	2·76	14·2	2·85	4·58	10·1
2000	17·8	16	12	0	31	19	12	535	7·6	2·91	14·9	3·20	5·20	10·7
2100	20·0	17	18	0	33	20	36	532	7·6	3·05	15·6	3·60	5·85	11·4
2200	22·8	18	24	0	36	22	6	529	7·0	3·20	16·3	4·00	6·65	12·1
2300	25·5	19	36	0	38	23	36	526	7·0	3·34	17·0	4·40	7·45	12·8
2400	28·5	20	48	0	41	25	12	523	7·0	3·49	17·7	4·90	8·35	13·5
2500	32·0	22	0	0	44	26	54	521	6·4	3·63	18·4	5·40	9·35	14·3
2600	35·8	23	18	0	47	28	42	519	6·4	3·78	19·1	6·00	10·50	15·1
2700	39·8	24	36	0	51	30	42	518	5·6	3·92	19·8	6·60	11·80	16·0
2800	44·0	26	6	0	54	32	48	519	5·6	4·07	20·5	7·20	13·20	16·9
2900	49·0	27	36	0	58	35	0	521	4·9	4·21	21·2	7·90	15·00	17·8
3000	55·0	29	18	1	3	37	24	524	4·5	4·36	21·9	8·60	16·80	18·7
3100	61·0	31	8	1	8	40	6	527	3·8	4·51	22·5	9·30	19·00	19·7
3200	69·0	33	18	1	14	43	12	531	3·3	4·65	23·1	10·10		20·7
3300	77·5	35	48	1	21	47	0	536	2·8	4·80	23·7	10·90		21·8

Charge, 2 lb. R.L.G.[2] powder. Muzzle velocity, 482 f.s.

400	1·8	4	30	0	16	5	0	466	6·4	0·58	2·4	0·10	0·21	2·6
500	2·4	5	48	0	17	6	24	463	6·4	0·72	3·0	0·16	0·34	3·2
600	3·2	7	6	0	18	7	48	460	6·4	0·87	3·6	0·22	0·49	3·8
700	4·0	8	24	0	20	9	12	457	6·4	1·01	4·2	0·28	0·68	4·5
800	5·0	9	42	0	22	10	36	454	6·3	1·16	4·8	0·40	0·90	5·2
900	6·0	11	2	0	23	12	12	451	6·0	1·31	5·4	0·55	1·17	5·9
1000	7·4	12	26	0	26	13	48	448	5·7	1·45	6·0	0·70	1·48	6·6
1100	9·0	13	54	0	28	15	30	445	5·6	1·60	6·6	0·85	1·84	7·3
1200	10·8	15	24	0	31	17	12	442	5·6	1·74	7·2	1·00	2·24	8·0
1300	12·8	16	54	0	34	19	0	439	5·2	1·89	7·8	1·20	2·69	8·8
1400	15·0	18	30	0	37	21	0	436	4·9	2·03	8·4	1·40	3·20	9·6
1500	17·5	20	12	0	40	23	0	434	4·6	2·18	9·0	1·60	3·80	10·5
1600	20·7	22	0	0	45	25	12	432	4·6	2·32	9·6	1·90	4·50	11·4
1700	25·0	23	48	0	51	27	30	430	4·2	2·47	10·1	2·20	5·25	12·4
1800	30·0	25	48	0	57	30	6	429	3·6	2·61	10·6	2·50	6·10	13·4
1900	36·5	28	6	1	6	33	0	428	3·2	2·76	11·1	2·85	7·20	14·5
2000	45·2	30	42	1	18	36	24	427	2·7	2·91	11·6	3·29	8·50	15·7
2100	58·5	33	48	1	36	41	12	427	1·6	3·05	12·1	3·60	10·70	17·0

Range Tables for the 6·3-inch R.M.L. Howitzer.
(Based on Practice of January, 1878, and May, 1879.)

Projectile, common shell, fitted with rotating gas-check; weight 70 lbs.
Charges, 4 and 2 lbs. R.L.G.[2] powder.
Charge, 4 lbs. R.L.G.[2] Muzzle velocity, 751 f.s.

Range.	Drift, right.	Elevation.	Deflection, left.	Angle of Descent.	Remaining Velocity.	Five minutes' elevation increases or decreases the Range by	Five minutes will alter point of impact vertically or laterally at each Range	50 per cent. of rounds should fall within			Time of Flight.	Fuse Scale.
								Length.	Breadth.	Height.		
yds.	yds.	° ′	° ′	° ′	f.s.	yds.	yds.	yds.	yds.	yds.	secs.	
400		1 42		2 12	721	15·1	0·58	7·0	0·13	0·27	1·7	
500	0·3	2 15	0 2	2 42	714	14·7	0·72	7·7	0·22	0·36	2·1	
600	0·6	2 49	0 3	3 18	707	14·7	0·87	8·6	0·31	0·49	2·5	
700	1·3	3 23	0 6	3 54	700	14·3	1·01	9·7	0·42	0·67	3·0	
800	2·1	3 58	0 9	4 30	693	14·3	1·16	10·6	0·53	0·85	3·5	
900	3·0	4 33	0 11	5 9	686	14·3	1·31	12·0	0·64	1·10	3·9	
1000	3·9	5 8	0 13	5 48	679	13·9	1·45	13·3	0·76	1·40	4·4	
1100	5·0	5 44	0 16	6 30	672	13·9	1·60	14·7	0·88	1·70	4·9	
1200	6·1	6 20	0 18	7 12	665	13·9	1·74	16·1	1·00	2·00	5·3	
1300	7·2	6 56	0 19	7 54	658	13·9	1·89	17·5	1·12	1·40	5·7	
1400	8·5	7 32	0 21	8 39	651	13·9	2·03	18·9	1·25	2·90	6·1	
1500	10·0	8 8	0 23	9 24	644	13·5	2·18	20·3	1·38	3·40	6·6	
1600	12·0	8 45	0 26	10 12	637	13·5	2·32	21·7	1·51	3·90	7·1	
1700	14·0	9 25	0 30	11 0	630	12·5	2·47	23·1	1·65	4·50	7·6	
1800	16·0	10 5	0 31	11 48	624	12·5	2·61	24·5	1·79	5·10	8·1	
1900	18·3	10 45	0 33	12 42	618	12·5	2·76	25·9	1·93	5·90	8·6	
2000	20·5	11 30	0 35	13 36	612	11·2	2·91	27·3	2·07	6·80	9·2	
2100	23·0	12 15	0 38	14 36	607	11·2	3·05	28·7	2·22	7·50	9·7	
2200	25·8	13 0	0 40	15 36	602	11·2	3·20	30·1	2·37	8·50	10·2	
2300	28·8	13 45	0 43	16 39	597	11·2	3·34	31·5	2·52	9·50	10·8	
2400	31·8	14 30	0 46	17 42	592	11·2	3·49	33·0	2·67	10·60	11·3	
2500	35·0	15 15	0 48	18 54	587	11·2	3·63	34·5	2·83	11·90	11·9	
2600	39·0	16 5	0 52	20 6	582	10·0	3·78	36·0	2·99	13·40	12·5	
2700	43·3	17 0	0 55	21 24	578	9·1	3·92	37·5	3·16	14·60	13·1	
2800	48·0	18 0	0 59	22 42	574	8·4	4·07	39·0	3·33	16·40	13·8	
2900	53·0	19 0	1 3	24 12	570	8·4	4·21	40·6	3·50	18·40	14·5	
3000	58·3	20 0	1 7	25 42	566	8·4	4·36	42·2	3·68	20·50	15·2	
3100	63·8	21 0	1 11	27 12	563	8·4	4·51	43·8	3·86		15·8	
3200	69·2	22 0	1 14	28 48	560	8·4	4·65	45·4	4·04		16·5	
3300	75·0	23 5	1 18	30 42	558	7·7	4·80	47·0	4·22		17·2	
3400	81·5	24 10	1 23	32 42	556	7·7	4·94	48·7	4·41		18·0	
3500	88·6	25 25	1 27	34 42	554	6·6	5·09	50·4	4·60		18·8	
3600	96·0	26 45	1 32	37 0	553	6·3	5·23	52·1	4·80		19·6	
3700	104·0	28 15	1 37	39 24	554	5·5	5·38	53·8	5·02		20·6	
3800	123·0	29 45	1 51	42 0	555	5·5	5·52	55·5	5·24		21·6	
3900	135·0	31 45	1 59	44 48	556	4·2	5·67	57·2	5·46		22·8	
4000	152·0	35 0	2 11	48 0	557	2·6	5·81	59·0	5·70		24·9	

Charge, 2 lbs. R.L.G.[2] powder. Muzzle velocity, 507 f.s.

400		4 30		4 57	486	6·7	0·58	5·2	0·12	0·45	2·3	
500	0·5	5 45	0 3	6 12	481	6·7	0·72	6·6	0·15	0·72	3·0	
600	1·8	7 0	0 10	7 30	476	6·7	0·87	8·0	0·36	1·06	3·7	
700	3·5	8 15	0 17	8 54	471	6·3	1·01	9·4	0·60	1·50	4·4	
800	5·5	9 35	0 24	10 24	466	5·8	1·16	10·8	0·85	2·00	5·1	
900	7·7	11 0	0 29	11 54	463	5·6	1·31	12·2	1·10	2·60	5·8	
1000	10·0	12 30	0 34	13 30	458	5·6	1·45	13·5	1·37	3·20	6·5	
1100	12·5	14 0	0 39	15 12	454	5·2	1·60	14·8	1·65	4·10	7·2	
1200	15·0	15 35	0 43	17 0	450	5·2	1·74	16·0	1·93	4·90	7·9	
1300	17·5	17 10	0 46	18 54	446	5·2	1·89	17·1	2·21	5·80	8·7	
1400	20·0	18 45	0 49	21 0	442	5·0	2·03	18·1	2·49	7·00	9·5	
1500	23·0	20 25	0 53	23 12	439	5·0	2·18	19·1	2·77	8·20	10·4	
1600	26·0	22 5	0 56	25 36	437	4·7	2·32	20·1	3·05	9·80	11·3	
1700	29·3	23 52	0 59	28 18	437	3·9	2·47	21·1	3·35	11·40	12·2	
1800	33·5	26 0	1 4	31 30	438	3·3	2·61	22·1	3·68	13·70	13·3	
1900	38·8	28 30	1 10	35 18	439	2·6	2·76	23·1	4·05	16·40	14·4	
2000	46·0	31 42	1 19	39 54	440	1·7	2·91	24·1	4·48	20·2	15·9	
2100	58·5	36 30	1 36	46 24	441	0·6	3·05	25·1	5·05		17·9	
2158	80·0	41 0	2 7	55 43	442	0·6	3·14	26·1	5·70		20·7	
2100	102·8	51 24	2 49	60 36	443	1·8	3·05	26·8	6·10		23·2	
2000	117·3	56 0	3 22	64 36	448	2·8	2·91	27·1	6·25		24·7	
1900	126·8	50 0	3 50	67 18	453	3·7	2·76	27·2	6·30		25·6	
1800	134·5	61 12	4 18	69 24	458	4·0	2·61	27·3	6·35		26·4	
1700	141·5	63 18	4 46	71 12	463	5·5	2·47	27·3	6·35		26·7	
1600	146·5	64 48	5 16	72 54	468	6·4	2·32	27·4	6·35		27·0	
1500	151·0	66 6	5 46	74 20	473	7·3	2·18	27·4	6·35		27·3	

Range Table for 9-pr. R.B.L. Gun of 6 cwt.

Charge, 1 lb. 2 oz. R.L.G.[2]
Projectile, segment or common shell.
M.V., 1,055 f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.	
			Range.	Tenths.
Yards.	° ′	″		
100	0 5	0·40		
200	0 14	0·70		
300	0 24	1·00		
400	0 36	1·35		
500	0 49	1·70		
600	1 4	2·00		
700	1 20	2·30		
800	1 36	2·65		
900	1 54	3·00		
1000	2 12	3·30		
1100	2 30	3·60		
1200	2 49	3·95		
1300	3 8	4·30		
1400	3 27	4·60		
1500	3 47	5·00		
1600	4 7	5·35		
1700	4 27	5·70		
1800	4 48	6·15		
1900	5 10	6·50		
2000	5 32	6·90		
2100	5 55	7·30		
2200	6 18	7·70		
2300	6 42	8·10		
2400	7 6	8·55		
2500	7 32	8·95		
2600	7 58	9·40		
2700	8 25	9·85		
2800	8 52	10·25		
2900	9 17	10·70		
3000	9 47	11·20		

Range Table for 12-pr. R.B.L. Gun of 8 cwt.

Charge, 1½ lb. R.L.G.[2]

Projectile, common or shrapnel shell.

M.V., 1,239 f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.	
			Range.	Tenths.
Yards.	° ′	″		
100	0 9	0·28	100	0·5
200	0 19	0·56	200	1
300	0 30	0·84	400	2
400	0 41	1·13	600	3
500	0 53	1·42	800	4
600	1 5	1·72	1,000	5
700	1 18	2·01	1,200	6
800	1 32	2·31	1,400	7
900	1 46	2·62	1,600	8
1,000	2 0	2·93	1,750	9
1,100	2 15	3·25	1,900	10
1,200	2 30	3·57	2,050	11
1,300	2 46	3·89	2,200	12
1,400	3 2	4·21	2,350	13
1,500	3 18	4·54	2,500	14
1,600	3 35	4·87	2,650	15
1,700	3 53	5·21	2,800	16
1,800	4 12	5·55	2,950	17
1,900	4 31	5·90	3,100	18
2,000	4 51	6·25	3,230	19
2,100	5 11	6·61	3,360	20
2,200	5 32	6·68	3,490	21
2,300	5 53	7·35	3,620	22
2,400	6 15	7·73	3,750	23
2,500	6 38	8·12	3,880	24
2,600	7 1	8·52		
2,700	7 25	8·93		
2,800	7 50	9·34		
2,900	8 15	9·76		
3,000	8 41	10·19		
3,100	9 8	10·62		
3,200	9 36	11·06		
3,300	10 4	11·51		
3,400	10 33	11·96		
3,500	11 3	12·42		
3,600	11 33	12·88		
3,700	12 3	13·35		

Range Table for 20-pr. R.B.L. Guns of 13 and 15 cwt

Charge, 2 lb. 8 oz. R.L.G.[2]
Projectile, common or segment shell, and solid shot.
M.V., 1,000 f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.	
			Range.	Tenths.
Yards.	° ′	″		
100	0 7	..	..	0·5
200	0 20	..	..	1
300	0 33	1·06	..	2
400	0 47	1·40	..	2·5
500	1 4	1·75	..	3·5
600	1 22	2·10	..	4
700	1 41	2·44	..	5
800	2 1	2·79	..	5·5
900	2 21	3·16	..	6·5
1,000	2 42	3·52	..	7·5
1,100	3 4	3·88	..	8
1,200	3 26	4·29	..	9
1,300	3 48	4·60	..	9·5
1,400	4 10	4·98	..	10·5
1,500	4 32	5·36	..	11·5
1,600	4 54	5·74	..	12
1,700	5 16	6·15	..	13
1,800	5 38	6·56	..	13·5
1,900	6 1	6·98	..	14
2,000	6 24	7·38	..	15
2,100	6 48	7·80	..	16
2,200	7 12	8·20	..	17
2,300	7 36	8·62	..	18
2,400	8 1	9·06	..	19
2,500	8 28	9·50	..	20
2,600	8 56	9·93		
2,700	9 25	10·37		
2,800	9 53	10·80		
2,900	10 22	11·26		
3,000	10 51	11·75		

Range Table for 20-pr. R.B.L. Gun of 16 cwt.

Charge, 2 lb. 8 oz. R.L.G.[2]
Projectile, shot or shell.
M.V., 1,130 f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.	
			Range.	Tenths.
Yards.	° ′	″		
100	0 11	0·30	..	1·5
200	0 25	0·60	..	3
300	0 39	0·90	..	5
400	0 53	1·25	..	6·5
500	1 8	1·60	..	8·5
600	1 23	1·90	..	10
700	1 38	2·25	..	12
800	1 53	2·60	..	13·5
900	2 9	2·90	..	15·5
1000	2 26	3·25	..	17·5
1100	2 44	3·60	..	19
1200	3 3	3·95	..	21
1300	3 22	4·30	..	23
1400	3 41	4·65	..	25
1500	4 0	5·00	..	27
1600	4 19	5·35	..	28·5
1700	4 38	5·70	..	30·5
1800	4 57	6·00	..	32·5
1900	5 16	6·35	..	34·5
2000	5 37	6·70	..	36·5
2100	5 58	7·10	..	38
2200	6 19	7·50	..	40
2300	6 40	7·85		
2400	7 1	8·20		
2500	7 22	8·60		
2600	7 43	8·95		
2700	8 4	9·30		
2800	8 25	9·70		
2900	8 46	10·05		
3000	9 7	10·40		
3100	9 28	10·80		
3200	9 49	11·20		
3300	10 10	11·55		
3400	10 32	11·90		
3500	10 54	12·35		

Range Table for 40-pr. R.B.L. Gun of 32 and 35 cwt.

Charge, 5 lb. R.L.G.[2]

Projectile, common shell, 40 lb.

M.V., 1,180 f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.	
			Range.	Tenths.
Yards.	° ′	″		
100	0 10	0·35	..	0·5
200	0 21	0·65	..	1
300	0 33	0·95	..	1·5
400	0 45	1·25	..	2
500	0 58	1·55	..	2·5
600	1 12	1·85	..	3·5
700	1 27	2·15	..	4
800	1 42	2·45	..	5
900	1 57	2·75	..	5·5
1,000	2 13	3·05	..	6
1,100	2 29	3·35	..	6·5
1,200	2 46	3·70	..	7·5
1,300	3 3	4·00	..	8
1,400	3 21	4·30	..	8·5
1,500	3 39	4·65	..	9·5
1,600	3 57	4·95	..	10
1,700	4 15	5·30	..	10·5
1,800	4 33	5·60	..	11
1,900	4 51	5·95	..	12
2,000	5 9	6·30	..	12·5
2,100	5 27	6·60	..	13·5
2,200	5 45	7·00	..	14
2,300	6 4	7·35	..	14·5
2,400	6 24	7·70	..	15·5
2,500	6 44	8·05	..	16
2,600	7 5	8·45	..	17
2,700	7 27	8·80	..	17·5
2,800	7 49	9·20	..	18·5
2,900	8 12	9·60	..	19
3,000	8 35	10·00	..	20
3,100	8 58	10·40	..	21
3,200	9 22	10·80	..	22
3,300	9 46	11·25	..	22·5
3,400	10 10	11·65	..	23
3,500	10 35	12·05	..	24
3,600	11 00	12·45	..	25
3,700	11 25	12·90	..	26
3,800	11 50	13·35	..	27
3,900	12 16	13·80	..	27·5
4,000	12 42	14·25	..	28·5

Range Table for 7-inch R.B.L Gun of 72 cwt.

Charge, 10 b. R.L.G.[2]

Projectile, common shell.

M.V., 1,165 f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.	
			Range.	Tenths.
Yards.	° ′	″		
200	0 16	0·60	150	1
300	0 27	0·90	305	2
400	0 40	1·20	460	3
500	0 58	1·50	615	4
600	1 15	1·85	770	5
700	1 32	2·22	920	6
800	1 50	2·60	1,070	7
900	2 7	2·90	1,220	8
1,000	2 24	3·30	1,360	9
1,100	2 41	3·65	1,500	10
1,200	2 58	3·95	1,640	11
1,300	3 15	4·30	1,710	12
1,400	3 33	4·60	1,910	13
1,500	3 50	5·00	2,040	14
1,600	4 8	5·30	2,170	15
1,700	4 26	5·70	2,300	16
1,800	4 45	6·10	2,425	17
1,900	5 5	6·40	2,550	18
2,000	5 24	6·80	2,675	19
2,100	5 45	7·20	2,800	20
2,200	6 5	7·60	2,920	21
2,300	6 24	7·90	3,040	22
2,400	6 45	8·35	3,160	23
2,500	7 7	8·75	3,280	24
2,600	7 29	9·20	3,390	25
2,700	7 51	9·60	3,500	26
2,800	8 13	10·00		
2,900	8 35	10·40		
3,000	8 57	10·80		
3,100	9 20	11·25		
3,200	9 44	11·70		
3,300	10 8	12·10		
3,400	10 33	12·50		
3,500	10 58	13·00		

Range Table for 7-inch R.B.L. Gun of 82 cwt.

Charge, 11 lb. R.L.G.[2]
Projectile, shot, 68 lb.
M.V., f.s.

Range.	Elevation.	Time of Flight.
Yards.	° '	
100	0 7	
200	0 18	
300	0 30	
400	0 42	
500	0 54	
600	1 6	
700	1 18	
800	1 32	
900	1 46	
1,000	2 0	
1,100	2 14	
1,200	2 29	
1,300	2 44	
1,400	2 59	
1,500	3 15	
1,600	3 31	
1,700	3 47	
1,800	4 4	
1,900	4 21	
2,000	4 38	
2,100	4 56	
2,200	5 14	
2,300	5 32	
2,400	5 51	
2,500	6 10	
2,600	6 30	
2,700	6 50	
2,800	7 10	
2,900	7 30	
3,000	7 50	
3,100	8 10	
3,200	8 30	
3,300	8 51	
3,400	9 12	
3,500	9 33	
3,600	9 54	
3,700	10 15	

Range Table for 7-inch R.B.L. Gun of 82 cwt.

Charge, 11 lb. R.L.G.[2]

Projectile, common shell, 90 lb.

M.V., 1165 f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.	
			Range.	Tenths.
Yards.	° ′	″		
100	0 9	0·26	185	1
200	0 21	0·56	350	2
300	0 33	0·86	510	3
400	0 45	1·16	670	4
500	0 58	1·46	825	5
600	1 11	1·77	975	6
700	1 25	2·08	1,130	7
800	1 40	2·39	1,285	8
900	1 55	2·71	1,445	9
1,000	2 10	3·03	1,600	10
1,100	2 26	3·34	1,745	11
1,200	2 43	3·66	1,895	12
1,300	3 0	4·00	2,040	13
1,400	3 17	4·30	2,190	14
1,500	3 34	4·61	2,335	15
1,600	3 52	4·95	2,475	16
1,700	4 11	5·29	2,620	17
1,800	4 30	5·61	2,765	18
1,900	4 49	5·95	2,905	19
2,000	5 8	6·29	3,045	20
2,100	5 27	6·62	3,180	21
2,200	5 47	6·97	3,310	22
2,300	6 7	7·30	3,440	23
2,400	6 27	7·65	3,575	24
2,500	6 47	7·97	3,705	25
2,600	7 7	8·31	3,830	26
2,700	7 27	8·65	3,955	27
2,800	7 47	9·00	4,075	28
2,900	8 7	9·36		
3,000	8 27	9·71		
3,100	8 47	10·06		
3,200	9 7	10·42		
3,300	9 27	10·80		
3,400	9 47	11·17		
3,500	10 7	11·63		
3,600	10 27	12·00		

Range Table for 12-pr. B.L. Gun.

Based on Practice of 2. to 24. 10. 84.; 24. 3. 85.; 4. 5. 85.; 26. and 28. 5. 85.

Charge, 4lb. S. P.; gravimetric density, $\frac{29·5}{0·940}$
Projectile, Weight 12½ lb.

Carriage, Field, Armstrong.
Jump, 22 minutes.
Muzzle velocity, 1710 f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.		Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	50 per cent. of rounds should fall within		
			Armstrong time and concussion.	9 secs. R. L.					Length.	Breadth.	Length.
yards.	° ′	seconds.			° ′	f.s.	yards.	yards.	yards.	yards.	yards.
0											
100	0 17*	0·18			0 6	1664	74	0·14	24	·04	·04
200	0 11*	0·37		1·	0 12	1619	71	0·29	24	·09	·69
300	0 5*	0·56		1·51	0 19	1574	69	0·43	23	·14	·14
400	0 2	0·76		2·02	0 26	1530	67	0·58	23	·19	·19
500	0 9	0·96		2·55	0 35	1488	66	0·72	22	·24	·24
600	0 17	1·17		3·08	0 44	1446	64	0·87	22	·29	·29
700	0 25	1·38		3·62	0 54	1406	62	1·01	22	·34	·34
800	0 33	1·60		4·17	1 5	1367	61	1·16	21	·39	·39
900	0 42	1·83		4·72	1 16	1329	59	1·31	21	·45	·45
1000	0 51	2·07		5·28	1 28	1293	57	1·45	20	·50	·51
1100	1 1	2·31		5·85	1 41	1259	55	1·60	20	·55	·57
1200	1 11	2·56	0·55	6·42	1 54	1226	53	1·74	20	·62	·64
1300	1 21	2·82	0·78	7·00	2 8	1195	51	1·89	20	·68	·71
1400	1 31	3·08	1·02	7·59	2 23	1167	49	2·03	19	·75	·79
1500	1 42	3·35	1·15	8·19	2 38	1139	47	2·18	19	·81	·88
1600	1 52	3·62	1·28	8·70	2 54	1113	45	2·32	19	·88	·98
1700	2 3	3·90	1·41	9·32	3 11	1091	44	2·47	20	·95	1·10
1800	2 14	4·18	1·54	9·95	3 29	1069	42	2·61	20	1·02	1·20
1900	2 26	4·37	1·66	10·59	3 47	1048	41	2·76	20	1·10	1·35
2000	2 38	4·76	1·79	11·24	4 6	1028	40	2·91	21	1·18	1·50
2100	2 50	5·06	1·92	11·90	4 25	1010	39	3·05	21	1·26	1·7
2200	3 3	5·36	2·05	12·56	4 45	993	38	3·20	21	1·34	1·8
2300	3 16	5·66	2·19	13·23	5 6	977	37	3·34	21	1·43	2·0
2400	3 29	5·97	2·34	13·91	5 27	962	36	3·49	22	1·52	2·2
2500	3 42	6·28	2·48	14·61	5 50	947	35	3·63	22	1·61	2·4
2600	3 55	6·59	2·64	15·32	6 14	933	34	3·78	23	1·70	2·6
2700	4 9	6·90	2·81	16·05	6 39	930	33	3·92	23	1·80	2·8
2800	4 23	7·22	2·98	16·77	7 3	917	33	4·07	24	1·90	3·0
2900	4 37	7·54	3·15	17·5	7 29	905	32	4·21	24	2·01	3·2
3000	4 51	7·86	3·31		7 55	894	32	4·36	25	2·12	3·5
3100	5 6	8·19	3·48		8 21	883	31	4·51	25	2·23	3·8
3200	5 22	8·52	3·65		8 48	872	31	4·65	25	2·34	4·0
3300	5 39	8·85	3·83		9 16	861	29	4·80	26	2·45	4·3
3400	5 56	9·19	4·01		9 46	851	29	4·94	26	2·57	4·6
3500	6 12	9·53	4·19		10 16	841	28	5·09	27	2·69	5·0
3600	6 29	9·87	4·37		10 46	831	27	5·23	27	2·82	5·4
3700	6 46	10·20	4·55		11 17	821	27	5·38	28	2·96	5·8
3800	7 4	10·60	4·74		11 49	810	26	5·52	28	3·08	6·1
3900	7 22	11·0	4·93		12 22	801	26	5·67	29	3·23	6·4
4000	7 41	11·40			12 55	792	25	5·81	29	3·38	6·8
4100	8 0	11·80			13 31	783	25	5·96	30	3·54	7·2
4200	8 19	12·20			14 7	774	24	6·11	30	3·70	7·7
4300	8 40	12·60			14 44	765	24	6·25	30	3·87	8·2
4400	9 0	13·0			15 22	756	23	6·40	30	4·05	8·6
4500	9 21	13·40			15 59	747	23	6·54	31	4·20	9·1
4600	9 42	13·80			16 40	738	22	6·69			
4700	10 3	14·20			17 20	729	21	6·83			
4800	10 25	14·60			18 1	721	21	6·98			
4900	10 48	15·10			18 42	713	20	7·13			
5000	11 11	15·50			19 23	705	20	7·27			
5100	11 34	16·0			20 4	697	20	7·42			
5200	11 57	16·40			20 46	689	19	7·56			
5300	12 22	16·90			21 30	681	19	7·71			
5400	12 48	17·40			22 16	673	19	7·85			
5500	13 14	17·80			23 3	665	18	8·00			
5600	13 40	18·30			23 55	657	18	8·14			
5700	14 7	18·80			24 44	649	18	8·29			
5800	14 35	19·20			25 36	642	17	8·43			
5900	15 2	19·70			26 30	635	17	8·58			
6000	15 30	20·20			27 25	628	17	8·73			

* **Depression. Owing to the large jump, depression will have to be given up to 400 yards range.**

Range Table for 4-inch B.L. Gun of 13 cwt.

Based on Practice of 4. and 9. 5. 81., 12. to 28. 7. 81., and 9. 6. 84.

Charge, 3½ lb. B.L.G.[2]
Projectile, 25 lbs.
Mounting, Vavasseur.
Jump, 6 minutes.
Twist of rifling, increasing to 1 turn in 35 calibres.
Muzzle velocity, 1180 f.s.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within			Time of Flight.	Fuze scale.—Armstrong medium time and concussion fuze.
						Length.	Breadth.	Height.		
yds.	° ′	° ′	f.s.	1 in	yds.	yds.	yds.	yds.	secs.	ins.
100	0 7	0 14	1173	245	409	8·5	0·03	0·03	0·26	
200	0 20	0 28	1148	123	205	8·5	0·06	0·07	0·52	
300	0 33	0 42	1123	82	136	8·5	0·09	0·10	0·78	
400	0 46	0 56	1100	61	102	8·5	0·13	0·14	1·06	
500	0 59	1 11	1079	48	81	8·5	0·16	0·17	1·32	
600	1 13	1 26	1060	40	67	8·5	0·19	0·21	1·60	
700	1 27	1 41	1041	34	57	8·5	0·23	0·25	1·88	
800	1 41	1 57	1024	29	49	8·5	0·26	0·29	2·17	0·40
900	1 55	2 14	1009	26	43	8·5	0·30	0·33	2·47	0·75
1000	2 10	2 33	995	22	37	8·5	0·34	0·38	2·77	0·96
1100	2 25	2 51	980	20	33	8·6	0·38	0·43	3·08	1·12
1200	2 40	3 10	967	18	30	8·7	0·43	0·48	3·39	1·27
1300	2 56	3 30	954	16	27	8·8	0·47	0·54	3·71	1·42
1400	3 12	3 51	941	14	25	8·9	0·51	0·59	4·03	1·58
1500	3 28	4 12	929	13	23	9·0	0·56	0·65	4·36	1·74
1600	3 45	4 33	917	13	21	9·1	0·60	0·71	4·69	1·90
1700	4 2	4 55	905	12	19	9·2	0·65	0·78	5·02	2·06
1800	4 19	5 18	893	11	18	9·3	0·70	0·85	5·36	2·22
1900	4 37	5 41	882	10	17	9·4	0·75	0·93	5·70	2·39
2000	4 55	6 5	872	9·4	16	9·5	0·80	1·01	6·04	2·56
2100	5 14	6 30	862	8·8	15	9·7	0·86	1·01	6·39	2·74
2200	5 33	6 56	852	8·2	14	9·9	0·91	1·14	6·74	2·93
2300	5 52	7 22	842	7·7	13	10·2	0·97	1·29	7·10	3·12
2400	6 12	7 49	833	7·3	12	10·5	1·03	1·45	7·46	3·31
2500	6 32	8 17	824	6·9	11	11·1	1·09	1·62	7·83	3·51
2600	6 53	8 46	814	6·5	11	11·7	1·15	1·80	8·20	3·70
2700	7 14	9 16	805	6·1	10	12·3	1·22	2·02	8·58	3·90
2800	7 35	9 47	796	5·8	10	13·0	1·28	2·26	8·96	4·09
2900	7 57	10 19	787	5·5	9	13·8	1·35	2·53	9·35	4·28
3000	8 19	10 52	778	5·2	9	14·6	1·42	2·82	9·74	4·47
3100	8 42	11 26	770	4·9	8	15·5	1·49	3·2	10·14	4·66
3200	9 5	12 1	761	4·7	8	16·4	1·56	3·5	10·54	4·85
3300	9 28	12 37	753	4·5	7	17·4	1·63	3·9	10·95	
3400	9 52	13 14	745	4·3	7	18·4	1·70	4·3	11·4	
3500	10 16	13 52	737	4·1	7	19·5	1·78	4·8	11·8	
3600	10 41	14 30	729	3·9	6	20·6	1·85	5·3	12·2	
3700	11 6	15 9	721	3·7	6	21·7	1·93	5·9	12·65	
3800	11 32	15 49	714	3·5	6	22·9	2·01	6·5	13·1	
3900	11 58	16 30	706	3·4	6	24·1	2·19	7·2	13·5	
4000	12 25	17 12	698	3·2	5	25·3	2·27	7·9	13·9	
4100	12 52	17 54	690	3·1	5				14·3	
4200	13 20	18 37	683	3·0	5				14·75	
4300	13 48	19 21	675	2·8	5				15·2	
4400	14 16	20 5	668	2·7	5				15·6	
4500	14 45	20 51	660	2·6	4				16·0	
4600	15 14	21 37	653	2·5	4				16·45	
4700	15 44	22 24	645	2·4	4				16·9	
4800	16 14	23 11	638	2·3	4				17·3	
4900	16 45	23 59	631	2·2	4				17·8	
5000	17 16	24 47	624	2·2	4				18·2	
5100	17 48	25 36	617	2·1	3				18·7	
5200	18 20	26 26	610	2·0	3				19·2	
5300	18 53	27 17	603	1·9	3				19·6	
5400	19 27	28 8	596	1·9	3				20·1	
5500	20 1	29 0	589	1·8	3				20·6	

Range Table for 6-pr. Hotchkiss Quick-Firing B.L. Gun.

Based on Practice of 22. to 24. 10. 83., 10. and 13. 4. 85., and 9. 7. 85.

Charge, 1 lb. 15¼ oz, C^2 (Sevan Livry).
Gravimetric density, $\frac{27 \cdot 7}{1 \cdot 0}$.
Projectile, weight 6 lb.
Muzzle velocity, 1818 f.s.
Mounting, cone.
Jump, 4 minutes negative.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an Object 10 ft. high, Range must be known within	Remaining Velocity.	Penetration, Wrought-iron.	50 per cent. of Rounds should fall within			Time of Flight.	Fuze Scale.
							Length.	Breadth.	Height.		
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	feet.	secs.	
0					1818	4·6					
100	0 9	0 5	687	1146	1762	4·5	34	0·1	0·2		
200	0 14	0 11	312	521	1708	4·3	33	0·1	0·4		
300	0 20	0 18	191	318	1655	4·2	32	0·2	0·5		
400	0 26	0 25	138	239	1603	4·0	32	0·3	0·7		
500	0 32	0 32	107	179	1552	3·9	31	0·3	0·9		
600	0 38	0 40	86	143	1503	3·8	31	0·4	1·1		
700	0 45	0 49	70	117	1454	3·6	30	0·5	1·3		
800	0 52	0 58	59	99	1407	3·5	30	0·5	1·6		
900	1 0	1 8	51	84	1352	3·4	30	0·6	1·8		
1000	1 8	1 19	44	72	1319	3·2	29	0·6	2·0		
1100	1 17	1 31	38	63	1278	3·1	29	0·7	2·3		
1200	1 26	1 43	33	55	1240	3·0	29	0·7	2·6		
1300	1 35	1 56	29	49	1203	2·9	29	0·8	3·0		
1400	1 45	2 11	26	44	1168	2·8	28	0·9	3·3		
1500	1 55	2 27	23	39	1136	2·7	28	1·0	3·7		
1600	2 5	2 44	21	35	1105	2·7	28	1·1	4·1		
1700	2 16	3 2	19	31	1078	2·6	28	1·2	4·5		
1800	2 27	3 21	17	28	1050	2·5	28	1·3	5·0		
1900	2 38	3 41	16	26	1030	2·5	28	1·4	5·5		
2000	2 50	4 2	14	24	1012	2·4	28	1·5	6·0		
2100	3 2	4 24	13	22	995	2·4	28	1·7	6·5		
2200	3 14	4 46	12	20	979	2·3	28	1·8	7·1		
2300	3 27	5 9	11	18	964	2·3	29	1·9	7·7		
2400	3 40	5 33	10	17	949	2·3	29	2·1	8·3		
2500	3 53	5 57	9·6	16	935	2·2	29	2·2	9·0		
2600	4 6	6 22	9·0	15	921	2·2	29	2·4	9·8		
2700	4 20	6 47	8·4	14	907	2·1	30	2·5	11		
2800	4 34	7 13	7·9	13	894	2·1	30	2·7	11		
2900	4 48	7 40	7·4	12	881	2·1	30	2·8	12		
3000	5 2	8 7	7·0	12	868	2·0	30	3·0	13		
3100	5 17	8 35	6·6	11	856	2·0	31	3·2	14		
3200	5 32	9 5	6·3	10	844	2·0	31	3·3	15		
3300	5 48	9 37	5·9	10	832	1·9	31	3·5	16		
3400	6 4	10 11	5·6	9	821	1·9	31	3·7	17		
3500	6 21	10 47	5·3	9	810	1·9	32	3·9	18		
3600	6 39	11 26	4·9	8	799	1·8	32	4·1	19		
3700	6 57	12 7	4·6	8	788	1·8	32	4·4	21		
3800	7 16	12 50	4·4	7	777	1·8	32	4·6	22		
3900	7 36	13 34	4·1	7	766	1·7	33	4·8	24		
4000	7 57	14 19	3·9	7	756	1·7		5·3	25		
4100	8 19	15 6	3·7	6	746	1·7					
4200	8 41	15 54	3·5	6	736	1·7					
4300	9 4	16 42	3·3	6	727	1·6					
4400	9 28	17 31	3·2	5	717	1·6					
4500	9 53	18 21	3·0	5	708	1·6					

Range Table for 4-in. B.L. Gun of 22 cwt., Mark I.
(Revised 11. 85.)

Based on Practice of 1. 1. 83.; 17. 1. 83.; 9. 6. 84.; 30. 7. 84.

Charge, 12 lb. S.P.; gravimetric density, $\frac{38 \cdot 4}{0 \cdot 722}$.
Projectile, weight 25 lb.
Muzzle velocity, 1790 f.s.
Mounting, Vavasseur broadside.
Jump, 6 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	50 per cent. of rounds should fall within			Time of Flight.	Estimated fuze scale for Armstrong medium time and concussion fuze. Based on practice of 1. 1. 83. (with a very low brand of powder).
						Length.	Breadth.	Height.		
yds.	° ′	° ′	1 in	yds.	f.s.	yds.	yds.	yds.	secs.	
0					1790					
100		0 5	687	1145	1745	There is not sufficient data for a precise estimate of the accuracy. It may, however, be taken as equal to that of the 4-inch Mark II gun at similar elevations.			0·17	
200	0 4	0 11	312	521	1701				0·35	
300	0 10	0 17	202	337	1658				0·54	
400	0 15	0 23	149	249	1615				0·73	
500	0 21	0 30	115	191	1573				0·93	
600	0 27	0 37	93	155	1531				1·13	
700	0 33	0 45	76	127	1490				1·34	
800	0 40	0 54	64	106	1451				1·55	
900	0 47	1 4	54	90	1412				1·76	
1000	0 55	1 14	46	77	1374				1·98	
1100	1 3	1 25	40	67	1337				2·20	
1200	1 11	1 37	35	59	1302				2·42	0·40
1300	1 20	1 49	31	52	1269				2·65	0·65
1400	1 29	2 2	28	46	1238				2·89	0·86
1500	1 38	2 16	25	42	1209				3·13	1·04
1600	1 47	2 30	23	38	1181				3·38	1·20
1700	1 56	2 45	21	35	1155				3·55	1·36
1800	2 6	3 0	19	32	1130				3·83	1·52
1900	2 16	3 16	18	29	1106				4·11	1·68
2000	2 27	3 32	16	27	1084				4·40	1·84
2100	2 38	3 49	15	25	1064				4·69	2·0
2200	2 49	4 7	14	23	1045				5·0	2·16
2300	3 0	4 25	13	22	1027				5·30	2·32
2400	3 12	4 44	12	20	1011				5·60	2·48
2500	3 24	5 3	11	19	996				5·90	2·64
2600	3 36	5 23	11	18	982				6·21	2·80
2700	3 49	5 43	10	17	969				6·52	2·96
2800	4 2	6 4	9·4	16	956				6·84	3·12
2900	4 15	6 25	8·9	15	943				7·16	3·29
3000	4 29	6 47	8·4	14	931				7·49	3·45
3100	4 42	7 9	8·0	13	920				7·82	3·61
3200	4 56	7 32	7·6	13	908				8·15	3·78
3300	5 10	7 56	7·2	12	896				8·48	3·94
3400	5 25	8 20	6·8	11	885				8·81	4·11
3500	5 40	8 44	6·5	11	875				9·14	4·28
3600	5 55	9 9	6·2	10	865				9·47	4·45
3700	6 11	9 34	5·9	10	855				9·80	4·62
3800	6 26	10 0	5·7	9	845				10·1	4·79
3900	6 42	10 27	5·4	9	835				10·5	4·96

RANGE TABLE FOR 4-IN. B.L. GUN OF 22 CWT., MARK I.—*continued.*

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	50 per cent. of rounds should fall within			Time of Flight.	Estimated fuze scale for Armstrong medium time and concussion fuze. Based on practice of 1. 1. 83. (with a very low brand of powder).
						Length.	Breadth.	Height.		
yds.	° ′	° ′	1 in	yds.	f.s.	yds.	yds.	yds.	secs.	
4000	6 59	10 54	5·2	9	826	There is not sufficient data for a precise estimate of the accuracy. It may, however, be taken as equal to that of the 4-inch Mark II gun at similar elevations.			10·8	
4100	7 16	11 22	5·0	8	817				11·2	
4200	7 33	11 51	4·8	8	808				11·5	
4300	7 50	12 21	4·6	8	799				11·9	
4400	8 8	12 51	4·4	7	790				12·3	
4500	8 26	13 22	4·2	7	782				12·6	
4600	8 44	13 53	4·0	7	774				13·0	
4700	9 2	14 25	3·9	6	766				13·4	
4800	9 21	14 57	3·7	6	759				13·8	
4900	9 40	15 29	3·6	6	750				14·2	
5000	10 0	16 2	3·5	6	742				14·6	
5100	10 20	16 35	3·4	6	734				15·0	
5200	10 40	17 9	3·2	5	726				15·4	
5300	11 1	17 43	3·1	5	718				15·8	
5400	11 22	18 18	3·0	5	710				16·2	
5500	11 43	18 53	2·9	5	703				16·6	
5600	12 4	19 29	2·8	5	696				17·0	
5700	12 26	20 6	2·7	5	689				17·4	
5800	12 48	20 44	2·6	4	681				17·8	
5900	13 10	21 23	2·6	4	674				18·2	
6000	13 32	22 3	2·5	4	666				18·7	
6100	13 55	22 44	2·4	4	659				19·1	
6200	14 18	23 26	2·3	4	651				19·5	
6300	14 41	24 9	2·2	4	644				19·9	
6400	15 5	24 54	2·2	4	637				20·4	
6500	15 29	25 40	2·1	3	630				20·9	
6600	15 54	26 27	2·0	3	623				21·3	
6700	16 19	27 16	1·9	3	616				21·8	
6800	16 46	28 6	1·9	3	609				22·2	
6900	17 13	28 58	1·8	3	602				22·7	
7000	17 41	29 52	1·7	3	596				23·2	
7100	18 9	30 49	1·7	3	590				23·6	
7200	18 38	31 48	1·6	3	584				24·1	
7300	19 8	32 50	1·5	3	578				24·5	
7400	19 39	33 55	1·5	2	572				25·0	

Range Table for 4-inch B.L. Guns, Marks II. and III.

To supersede Range Table dated 9. 8. 82.

Based on Practice of 17. 5. 83., 7. 3. 84., 21. and 23. 4. 84.

Charge, 12 lb. S.P.
Projectile, 25 lb.
Muzzle velocity, 1900 f.s.*
Mounting, Vavasseur.
Jump, 6 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within			Time of Flight.	Fuze Scale.—Armstrong medium fuze.
						Length.	Breadth.	Height.		
yards.	° ′	° ′	f.s.	1 in	yards.	yards.	yards.	yards.	secs.	inches.
100		0 5	1853	687	1146	24·0	0·04	0·04	0·15	
200	0 3	0 10	1806	344	573	23·9	0·07	0·08	0·31	
300	0 8	0 15	1760	229	382	23·7	0·11	0·12	0·47	
400	0 13	0 21	1715	164	273	23·6	0·15	0·17	0·64	
500	0 18	0 27	1671	127	212	23·5	0·19	0·21	0·82	
600	0 23	0 34	1628	101	169	23·3	0·23	0·26	1·00	
700	0 29	0 41	1585	84	140	23·1	0·27	0·30	1·19	
800	0 35	0 49	1543	70	119	22·8	0·31	0·35	1·39	
900	0 42	0 58	1502	59	99	22·5	0·35	0·39	1·59	
1000	0 49	1 8	1462	51	84	22·2	0·39	0·44	1·80	
1100	0 55	1 18	1423	44	73	22·0	0·43	0·49	2·01	
1200	1 3	1 29	1385	39	64	21·8	0·47	0·55	2·23	
1300	1 11	1 40	1348	34	57	21·6	0·52	0.62	2·46	0·52
1400	1 19	1 51	1313	31	52	21·4	0·56	0·69	2·69	0·75
1500	1 27	2 3	1280	28	47	21·1	0·60	0·76	2·93	0·95
1600	1 35	2 15	1248	25	42	20·9	0·65	0·83	3·18	1·10
1700	1 44	2 28	1218	23	39	20·7	0·69	0·91	3·44	1·23
1800	1 53	2 42	1190	21	35	20·5	0·73	0·99	3·69	1·36
1900	2 2	2 57	1163	19	32	20·3	0·78	1·07	3·95	1·49
2000	2 11	3 13	1138	18	30	20·0	0·82	1·16	4·21	1·62
2100	2 21	3 29	1113	16	27	20·0	0·87	1·25	4·48	1·75
2200	2 32	3 46	1091	15	25	20·0	0·91	1·35	4·76	1·89
2300	2 43	4 3	1070	14	24	20·0	0·96	1·46	5·05	2·03
2400	2 54	4 21	1051	13	22	20·3	1·00	1·57	5·34	2·17
2500	3 5	4 39	1033	12	20	20·3	1·05	1·68	5·64	2·32
2600	3 16	4 57	1016	12	19	20·4	1·10	1·79	5·94	2·47
2700	3 28	5 16	1001	11	18	20·5	1·15	1·91	6·25	2·63
2800	3 40	5 35	987	10	17	20·7	1·20	2·04	6·56	2·79
2900	3 52	5 54	973	9·7	16	20·9	1·25	2·17	6·88	2·95
3000	4 4	6 13	960	9·2	15	21·3	1·31	2·30	7·20	3·12
3100	4 16	6 33	947	8·7	15	22·0	1·36	2·48	7·52	3·29
3200	4 29	6 53	935	8·3	14	22·7	1·42	2·68	7·83	3·46
3300	4 42	7 14	924	7·9	13	23·5	1·47	2·92	8·14	3·64
3400	4.55	7 36	912	7·5	12	24·3	1·53	3·20	8·46	3·82
3500	5 9	7 59	900	7·1	12	25·2	1·58	3·53	8·78	4·0
3600	5 23	8 22	889	6·8	11	26·1	1·64	3·87	9·11	4·18
3700	5 37	8 46	878	6·5	11	27·0	1·70	4·21	9·44	4·36
3800	5 51	9 11	868	6·2	10	28·0	1·77	4·54	9·78	4·54
3900	6 6	9 36	858	5·9	10	29·0	1·83	4·89	10·13	4·72
4000	6 21	10 2	848	5·6	9	30·0	1·90	5·24	10·49	4·90
4100	6 36	10 30	838	5·4	9	31·0	1·98	5·70	10·86	
4200	6 52	10 59	820	5·2	9	32·0	2·07	6·20	11·23	

Range Table for 4-inch B.L. Guns, Marks II. and III.—*continued.*

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within			Time of Fight.	Fuze Scale.—Armstrong medium fuze.
						Length.	Breadth.	Height.		
yards.	° ′	° ′	f.s.	1 in	yards.	yards.	yards.	yards.	secs.	
4300	7 8	11 29	820	4·9	8	33·0	2·16	6·72	11·60	
4400	7 24	12 0	810	4·7	8	34·0	2·25	7·36	11·98	
4500	7 41	12 31	801	4·5	8	35·0	2·35	7·88	12·36	
4600	7 58	13 2	792	4·3	7	36·0	2·47	8·42	12·74	
4700	8 16	13 34	783	4·1	7	37·0	2·59	9·00	13·13	
4800	8 34	14 6	775	4·0	7	38·0	2·72	9·64	13·52	
4900	8 53	14 39	766	3·8	6	39·0	2·86	10·31	13·91	
5000	9 12	15 13	758	3·7	6	40·0	3·0	11·0	14·3	
5100	9 31	15 48	750	3·5	6				14·7	
5200	9 51	16 24	742	3·4	6				15·1	
5300	10 11	17 0	734	3·3	5				15·5	
5400	10 31	17 37	726	3·1	5				15·9	
5500	10 51	18 14	718	3·0	5				16·3	
5600	11 12	18 54	710	2·9	5				16·9	
5700	11 33	19 34	703	2·8	5				17·1	
5800	11 54	20 15	695	2·7	5				17·5	
5900	12 15	20 57	688	2·6	4				18·0	
6000	12 36	21 39	680	2·5	4				18·4	
6100	12 57	22 22	673	2·4	4				18·9	
6200	13 19	23 5	665	2·3	4				19·3	
6300	13 42	23 49	658	2·3	4				19·8	
6400	14 5	24 33	650	2·2	4				20·3	
6500	14 28	25 18	643	2·1	4				20·8	
6600	14 52	26 4	636	2·0	3				21·3	
6700	15 16	26 50	629	2·0	3				21·8	
6800	15 41	27 37	621	1·9	3				22·4	
6900	16 6	28 26	614	1·8	3				22·9	
7000	16 32	29 16	607	1·8	3				23·5	
7100	16 59	30 7	600	1·7	3				24·0	
7200	17 27	30 58	594	1·7	3				24·6	
7300	17 55	31 50	587	1·6	3				25·1	
7400	18 23	32 43	581	1·6	3				25·6	
7500	18 52	33 36	574	1·5	3				26·2	
7600	19 22	34 30	568	1·5	2					
7700	19 52	35 24	562	1·4	2					

* Muzzle velocity with 12 lb. P. has been found to vary from 1980 to 1850 f.s., according to the brand of powder, but with P. powder selected for B.L. guns the muzzle velocity should not vary more than 20 f.s. from 1900 f.s. An increase of 100 f.s. in velocity increases the range at ordinary ranges about 7 per cent.

Range Table for 5-inch B.L. Gun.

Based on Practice of 23. 8. 83.

Charge, 8 lb. S.P., brand No. 824.
Projectile, weight 50 lb.
Muzzle velocity, 1200 f.s.
Jump, 6 minutes.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each range	50 per cent. of rounds should fall within			Time of Flight.	Fuze scale.—Armstrong medium.
						Length.	Breadth.	Height.		
yards.	° ′	° ′	f.s.	yards.	yards.	yards.	yards.	yards.	secs.	
100					0·14					
200	0 18	0 27	1153	39·5	0·29	9·0	0·07	0·07	0·50	
300	0 30	0 40	1132	39·0	0·43	9·7	0·12	0·12	0·76	
400	0 42	0 54	1113	38·5	0·58	10·4	0·17	0·17	1·02	
500	0 55	1 7	1094	38·0	0·72	10·9	0·22	0·22	1·29	
600	1 8	1 21	1079	37·5	0·87	11·4	0·27	0·27	1·56	
700	1 21	1 35	1065	37·0	1·01	11·6	0·32	0·32	1·83	
800	1 34	1 49	1051	36·6	1·16	11·7	0·36	0·37	2·11	
900	1 48	2 4	1037	36·1	1·31	11·8	0·41	0·43	2·39	0·47
1000	2 1	2 19	1023	35·7	1·45	11·9	0·46	0·48	2·67	0·72
1100	2 15	2 35	1009	35·3	1·60	12·0	0·51	0·54	2·96	0·95
1200	2 29	2 51	995	34·9	1·74	12·3	0·56	0·61	3·25	1·15
1300	2 43	3 7	983	34·5	1·89	12·8	0·61	0·70	3·54	1·33
1400	2 57	3 24	971	34·2	2·03	13·5	0·66	0·80	3·84	1·51
1500	3 12	3 41	960	33·8	2·18	14·2	0·72	0·92	4·14	1·68
1600	3 27	3 58	949	33·5	2·32	15·1	0·78	1·05	4·45	1·84
1700	3 42	4 15	939	33·1	2·47	15·9	0·83	1·17	4·76	2·00
1800	3 57	4 33	930	32·8	2·61	16·6	0·89	1·30	5·08	2·15
1900	4 12	4 51	921	32·4	2·76	17·1	0·95	1·44	5·40	2·31
2000	4 28	5 10	912	32·0	2·91	17·5	1·01	1·58	5·72	2·47
2100	4 44	5 29	903	31·6	3·05	17·8	1·08	1·73	6·04	2·63
2200	5 0	5 49	894	31·2	3·20	18·2	1·14	1·89	6·36	2·80
2300	5 16	6 10	885	30·7	3·34	18·6	1·20	2·06	6·69	2·97
2400	5 33	6 32	876	30·2	3·49	19·0	1·26	2·22	7·02	3·14
2500	5 50	6 54	867	29·8	3·63	19·5	1·33	2·39	7·35	3·31
2600	6 6	7 17	858	29·4	3·78	19·9	1·39	2·56	7·68	3·48
2700	6 23	7 40	850	29·0	3·92	20·3	1·46	2·74	8·02	3·66
2800	6 40	8 4	842	28·6	4·07	20·5	1·53	2·93	8·36	3·85
2900	6 58	8 28	834	28·2	4·21	20·7	1·59	3·12	8·71	4·05
3000	7 16	8 52	826	27·8	4·36	21·0	1·66	3·32	9·06	4·25
3100	7 34	9 18	819	27·5	4·51	21·4	1·73	3·54	9·42	4·46
3200	7 52	9 42	812	27·2	4·65	22·0	1·80	3·80	9·79	4·66
3300	8 10	10 7	805	26·8	4·80	22·8	1·87	4·10	10·15	4·86
3400	8 28	10 33	798	26·5	4·94	23·8	1·95	4·45	10·52	
3500	8 47	11 0	791	26·2	5·09	25·0	2·03	4·85	10·88	
3600	9 6	11 27	784	25·8	5·23	26·2	2·12	5·25	11·25	
3700	9 25	11 54	777	25·5	5·38	27·5	2·21	5·75	11·62	
3800	9 45	12 20	770	25·2	5·52	28·9	2·30	6·30	12·00	
3900	10 5	12 47	764	24·9	5·67	30·4	2·40	6·90	12·38	
4000	10 25	13 15	757	24·6	5·81	32·0	2·50	7·60	12·76	

Range Table for 5-inch B.L. Guns, Marks I. and II.

To supersede Range Table dated 12. 2. 84.

Based on Practice of 10. 7. 83., 23. 8. 83., 9. 10. 83., 31. 1. 84., 22. 2. 84., 19. 3. 84.

Charge, 16 lb. S.P.
Projectile, weight 50 lb.
Mounting, Vavasseur. Jump, 3 minutes negative.
Final twist of rifling { Mark I gun, 1 turn in 30 calibres.
 ,, II ,, ,, 25 ,,
Muzzle velocity { Mark I. gun, 1800 f.s.
 ,, II. ,, 1780 ,,

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within			Time of Flight.	Fuze scale.—Armstrong medium time and concussion fuze.
						Length.	Breadth.	Height.		
yards.	° ′	° ′	f.s.	1 in	yards.	yards.	yards.	yards.	secs.	inches.
100	0 8	0 6	1763	515	858	22·0	0·03	0·03	0·19	
200	0 13	0 12	1727	286	429	21·8	0·06	0·07	0·38	
300	0 18	0 17	1691	202	333	21·7	0·10	0·11	0·57	
400	0 23	0 23	1656	149	232	21·5	0·13	0·15	0·76	
500	0 29	0 29	1621	118	198	21·4	0·16	0·19	0·95	
600	0 34	0 35	1587	98	164	21·3	0·20	0·23	1·15	
700	0 40	0 42	1554	82	130	21·2	0·23	0·28	1·35	
800	0 46	0 50	1521	69	115	21·1	0·27	0·32	1·56	
900	0 53	0 58	1488	59	99	21·0	0·30	0·36	1·77	
1000	0 59	1 7	1456	51	86	21·0	0·34	0·41	1·98	
1100	1 6	1 16	1425	45	75	21·0	0·37	0·46	2·19	
1200	1 12	1 25	1394	40	67	21·0	0·41	0·51	2·40	
1300	1 19	1 35	1364	36	60	21·0	0·45	0·57	2·62	0·50
1400	1 26	1 45	1335	33	55	21·0	0·49	0·64	2·83	0·80
1500	1 34	1 56	1306	30	50	21·0	0·52	0·71	3·05	1·06
1600	1 42	2 7	1278	27	45	21·0	0·56	0·78	3·28	1·21
1700	1 50	2 19	1252	25	41	21·0	0·60	0·86	3·51	1·36
1800	1 58	2 32	1226	23	37	21·0	0·64	0·93	3·74	1·50
1900	2 7	2 45	1202	21	34	21·0	0·68	1·01	3·97	1·65
2000	2 16	2 58	1179	19	32	21·1	0·72	1·09	4·21	1·80
2100	2 25	3 12	1159	18	30	21·2	0·76	1·18	4·45	1·95
2200	2 34	3 26	1136	17	28	21·3	0·81	1·27	4·70	2·10
2300	2 43	3 40	1116	16	26	21·4	0·85	1·37	4·95	2·25
2400	2 52	3 55	1097	15	24	21·5	0·90	1·47	5·21	2·40
2500	3 2	4 10	1079	14	23	21·7	0·95	1·58	5·47	2·55
2600	3 11	4 25	1062	13	21	21·9	1·09	1·70	5·74	2·70
2700	3 21	4 40	1046	12	20	22·2	1·05	1·82	6·01	2·85
2800	3 31	4 56	1032	12	19	22·5	1·10	1·95	6·28	3·00
2900	3 41	5 12	1019	11	18	22·9	1·15	1·09	6·55	3·15
3000	3 52	5 28	1007	10	17	23·3	1·20	2·24	6·83	3·30
3100	4 3	5 44	996	10	17	23·7	1·25	2·40	7·11	3·45
3200	4 14	6 1	985	9·5	16	24·2	1·31	2·58	7·39	3·61
3300	4 25	6 18	975	9·0	15	24·7	1·36	2·77	7·67	3·76
3400	4 36	6 36	964	8·6	14	25·2	1·42	2·97	7·96	3·92
3500	4 48	6 54	954	8·3	14	25·8	1·48	3·18	8·25	4·08
3600	5 0	7 13	944	7·9	13	26·4	1·54	3·40	8·55	4·25
3700	5 12	7 33	934	7·5	13	27·0	1·60	3·64	8·85	4·42
3800	5 24	7 53	924	7·2	12	27·7	1·67	3·89	9·15	4·60
3900	5 37	8 14	914	6·9	12	28·4	1·73	4·15	9·46	4·77
4000	5 50	8 35	905	6·6	11	29·1	1·80	4·42	9·77	4·94
4100	6 3	8 56	895	6·3	11	29·8	1·88	4·70	10·1	
4200	6 16	9 18	886	6·1	10	30·5	1·96	5·0	10·4	
4300	6 29	9 40	877	5·8	10	31·2	2·04	5·32	10·7	

Range Table for 5-inch B.L. Guns, Marks I. and II.—*continued.*

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within			Time of Flight.	Fuze Scale.—Armstrong medium time and concussion fuse.
						Length.	Breadth.	Height.		
yards.	° ′	° ′	f.s.	1 in	yards.	yards.	yards.	yards.	secs.	inches.
4400	6 48	10 3	869	5·6	9	31·9	2·13	5·66	11·0	
4500	6 57	10 26	861	5·4	9	32·6	2·22	6·01	11·4	
4600	7 11	10 49	853	5·2	9	33·3	2·32	6·37	11·7	
4700	7 25	11 13	845	5·0	8	34·0	2·43	6·74	12·0	
4800	7 40	11 37	838	4·9	8	34·7	2·55	7·12	12·3	
4900	7 55	12 1	831	4·7	8	35·4	2·67	7·50	12·7	
5000	8 10	12 26	823	4·5	8	36·0	2·80	8·0	13·0	
5100	8 25	12 51	816	4·4	7				13·3	
5200	8 40	13 16	808	4·2	7				13·6	
5300	8 58	13 42	801	4·1	7				14·0	
5400	9 14	14 8	794	4·0	7				14·3	
5500	9 30	14 34	787	3·8	6				14·7	
5600	9 47	15 0	780	3·7	6				15·0	
5700	10 3	15 27	772	3·6	6				15·4	
5800	10 20	15 53	765	3·5	6				15·7	
5900	10 37	16 20	759	3·4	6				16·1	
6000	10 54	16 46	751	3·3	6				16·4	
6100	11 11	17 13	744	3·2	5				16·8	
6200	11 28	17 40	737	3·1	5				17·2	
6300	11 45	18 8	731	3·0	5				17·5	
6400	12 3	18 35	724	3·0	5				17·9	
6500	12 21	19 3	718	2·9	5				18·3	
6600	12 39	19 31	712	2·8	5				18·6	
6700	12 57	20 0	706	2·7	5				19·0	
6800	13 16	20 28	700	2·7	4				19·4	
6900	13 35	20 57	694	2·6	4				19·7	
7000	13 54	21 25	688	2·5	4				20·1	
7100	14 13	21 54	682	2·5	4				20·5	
7200	14 33	22 24	676	2·4	4				20·9	
7300	14 53	22 53	670	2·4	4				21·3	
7400	15 13	23 23	665	2·3	4				21·7	
7500	15 33	23 52	659	2·3	4				22·1	
7600	15 54	24 22	653	2·2	4				22·5	
7700	16 14	24 53	647	2·2	4				22·9	
7800	16 35	25 23	642	2·1	4				23·3	
7900	16 56	25 54	636	2·1	3				23·7	
8000	17 17	26 25	630	2·0	3				24·1	
8100	17 39	26 57	624	2·0	3				24·5	
8200	18 1	27 28	619	1·9	3				24·9	
8300	18 23	28 0	613	1·9	3				25·4	
8400	18 45	28 33	607	1·8	3				25·8	
8500	19 8	29 6	602	1·8	3				26·2	
8600	19 31	29 39	596	1·8	3				26·6	
8700	19 54	30 13	591	1·7	3				27·1	

Range Table for 6-inch B.L. 80-pr. Gun.

Based on Practice of 4. 5. 80., 21. 4. 81., 26. 9. 81.

Charge, 34 P.
Gravimetric density, $\frac{34\cdot0}{\cdot814}$.
Projectile, weight 80 lb.
Muzzle velocity, 1880 f.s.*
Mounting, Armstrong, broadside.
Jump, 5 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Five minutes' elevation increases or decreases the Range by	50 per cent. of rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Fuze Scale.—Armstrong Medium Time and Concussion Fuze.
yds.	° ′	° ′	1 in	yds.	f.s.	yds.	yds.	yds.	feet	secs.	
0					1880	10·5					
100		0 5	688	1146	1849	10·3	26	0·1	0·1	0·16	
200	0 5	0 10	344	573	1818	10·1	26	0·1	0·2	0·33	
300	0 10	0 16	215	360	1787	10·0	26	0·1	0·3	0·49	
400	0 16	0 23	149	249	1757	9·8	26	0·2	0·4	0·66	
500	0 21	0 28	123	206	1727	9·6	25	0·2	0·6	0·83	
600	0 26	0 34	101	169	1698	9·4	25	0·3	0·7	1·00	
700	0 32	0 40	86	143	1669	9·3	25	0·3	0·9	1·18	
800	0 37	0 47	73	122	1640	9·1	25	0·3	1·0	1·36	
900	0 43	0 54	64	106	1612	8·9	24	0·4	1·1	1·54	
1000	0 48	1 1	56	94	1584	8·7	24	0·4	1·3	1·73	
1100	0 54	1 9	50	83	1556	8·6	24	0·5	1·4	1·92	
1200	1 0	1 17	45	74	1529	8·4	24	0·5	1·6	2·11	0·40
1300	1 6	1 25	40	67	1502	8·2	24	0·5	1·7	2·31	0·61
1400	1 13	1 33	37	62	1475	8·1	24	0·6	1·9	2·51	0·81
1500	1 19	1 42	34	56	1449	7·9	24	0·6	2·1	2·72	1·00
1600	1 25	1 61	31	52	1423	7·7	24	0·7	2·3	2·93	1·17
1700	1 32	2 1	28	47	1398	7·6	24	0·7	2·5	3·14	1·33
1800	1 40	2 11	26	41	1373	7·4	24	0·8	2·7	3·35	1·49
1900	1 47	2 21	24	41	1349	7·3	24	0·8	2·9	3·57	1·65
2000	1 55	2 32	23	38	1325	7·2	24	0·9	3·1	3·79	1·81
2100	2 2	2 43	21	36	1302	7·0	24	0·9	3·4	4·01	1·96
2200	2 10	2 54	20	33	1280	6·9	25	1·0	3·6	4·24	2·11
2300	2 18	3 6	19	31	1259	6·8	25	1·0	3·9	4·47	2·26
2400	2 26	5 18	17	29	1238	6·6	25	1·1	4·2	4·71	2·42
2500	2 34	3 30	16	27	1218	6·5	25	1·2	4·5	4·95	2·58
2600	2 43	3 43	15	26	1199	6·4	25	1·2	4·8	5·19	2·73
2700	2 52	3 56	15	24	1180	6·3	25	1·3	5·2	5·44	2·88
2800	3 1	4 10	14	23	1162	6·1	25	1·3	5·5	5·69	3·03
2900	3 10	4 25	13	21	1144	6·0	25	1·4	5·9	5·95	3·17
3000	3 19	4 41	12	20	1127	5·9	25	1·5	6·3	6·21	3·32
3160	3 29	4 67	12	19	1110	5·8	25	1·5	5·7	6·47	3·46
3200	3 39	5 14	11	18	1094	5·7	26	1·6	7·2	6·74	3·61
3300	3 49	5 32	10	17	1079	5·6	26	1·7	7·6	7·01	3·76
3400	4 0	5 50	9·8	16	1065	5·6	26	1·8	8·1	7·29	3·91
3500	4 11	6 9	9·3	15	1052	5·5	26	1·8	8·5	7·58	4·05
3600	4 22	6 29	8·8	15	1041	5·4	26	1·9	9·0	7·87	4·20
3700	4 33	6 50	8·3	14	1031	5·3	27	2·0	9·5	8·16	4·35
3800	4 44	7 11	7·9	13	1021	5·3	27	2·1	10	8·46	4·50
3900	4 56	7 32	7·6	13	1011	5·2	27	2·2	10	8·76	4·64
4000	5 8	7 54	7·2	12	1002	5·1	28	2·2	11	9·06	4·79
4100	5 20	8 16	6·9	11	993	5·1	28	2·3	12	9·36	4·94

Range Table for 6-inch B.L. 80-pr. Gun—*continued.*

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Five minutes' elevation increases or decreases the Range by	50 per cent. of rounds should fall within			Time of Flight.	Fuze Scale.—Armstrong Medium Time and Concussion Fuze.
							Length.	Breadth.	Height.		
yds.	° ′	° ′	1 in	yds.	f.s.	yds.	yds.	yds.	feet	secs.	
4200	5 32	8 38	6·6	11	984	5·0	28	2·4	13	9·66	
4300	5 44	9 1	6·3	10	976	5·0	29	2·5	14	9·96	
4400	5 57	9 24	6·0	10	967	4·9	29	2·6	14	10·3	
4500	6 10	9 48	5·8	10	959	4·9	30	2·7	15	10·6	
4600	6 24	10 12	5·6	9	950	4·8	30	2·8	15	10·9	
4700	6 38	10 36	5·3	9	942	4·8	31	2·9	17	11·2	
4800	6 52	11 1	5·1	9	934	4·7	31	3·1	18	11·5	
4900	7 7	11 26	4·9	8	926	4·7	32	3·2	19	11·8	
5000	7 21	11 51	4·8	8	918	4·6	32	3·3	20	12·2	
5100	7 36	12 17	4·6	8	911	4·6				12·5	
5200	7 51	12 43	4·4	7	903	4·5				12·8	
5300	8 5	13 9	4·3	7	896	4·5				13·1	
5400	8 20	13 36	4·1	7	889	4·5				13·5	
5500	8 35	14 3	4.0	7	881	4·4				13·8	
5600	8 50	14 30	3·9	6	874	4·4				14·1	
5700	9 6	14 58	3·7	6	867	4·3				14·5	
5800	9 22	15 26	3·6	6	860	4·3				14·8	
5900	9 38	15 55	3·5	6	854	4·3				15·1	
6000	9 54	16 24	3·4	6	847	4·2				15·5	
6100	10 11	16 54	3·3	5	841	4·2				15·8	
6200	10 28	17 25	3·2	5	834	4·1				16·2	
6300	10 45	17 56	3·1	5	828	4·1				16·5	
6400	11 3	18 28	3·0	5	822	4·1				16·8	
6500	11 21	19 1	2·9	5	815	4·0				17·2	
6600	11 39	19 34	2·8	5	809	4·0				17·6	
6700	11 58	20 8	2·7	5	803	3·9				17·9	
6800	12 17	20 43	2·6	4	797	3·9				18·3	
6900	12 36	21 19	2·6	4	791	3·9				18·7	
7000	11 55	21 56	2·5	4	786	3·8				19·0	
7100	13 15	22 33	2·4	4	780	3·8				19·4	
7200	13 35	23 1	2·4	4	775	3·8				19·8	
7300	13 55	23 49	2·3	4	769	3·7				20·2	
7400	14 16	24 28	2·2	4	764	3·7				20·5	
7500	14 37	25 7	2·2	4	758	3·7				20·9	
7600	14 59	25 46	2·1	3	752	3·6				21·3	
7700	15 21	26 26	2·0	3	747	3·6				21·7	
7800	15 43	27 6	2·0	3	741	3·6				22·1	
7900	16 6	27 47	1·9	3	736	3·5				22·5	
8000	16 29	28 28	1·8	3	730	3·5				22·9	

* This velocity is about 20 f.s. below that given by average lots of S.P. in a new gun; this difference of 20 f.s. in velocity would cause a difference in range of about 17 yards per 1,000.

Range Table for 6-inch B.L. 80-pr. Gun.

Based on Practice of 5. 5. 80.

Charge, 25 lbs. P.
Projectile, weight 80 lb.
Muzzle velocity, 1575 f.s.

Gravimetric density, $\frac{46\cdot0}{0\cdot600}$.
Mounting, Armstrong, broadside.
Jump, 5 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Time of Flight.	Fuze scale.—Armstrong medium time and concussion fuze.
yds.	° ′	° ′	1 in	yds.	f.s.	secs.	fuze.
0					1575		
100	0 2	0 7	491	820	1547	0·19	
200	0 10	0 15	229	382	1520	0·38	
300	0 17	0 23	149	249	1493	0·58	
400	0 25	0 32	107	179	1467	0·78	
500	0 33	0 41	84	140	1441	0·99	
600	0 41	0 50	69	115	1416	1·20	
700	0 48	0 59	58	97	1391	1·42	
800	0 56	1 8	51	84	1366	1·64	
900	1 3	1 18	44	73	1342	1·86	
1000	1 11	1 28	39	65	1318	2·08	0·40
1100	1 19	1 38	35	58	1296	2·31	0·57
1200	1 28	1 49	32	53	1274	2·54	0·73
1300	1 37	2 0	29	48	1253	2·88	0·89
1400	1 46	2 12	26	44	1232	3·12	1·04
1500	1 56	2 24	24	40	1212	3·37	1·18
1600	2 6	2 37	22	37	1193	3·62	1·32
1700	2 17	2 50	20	34	1174	3·88	1·46
1800	2 28	3 4	19	31	1156	4·14	1·60
1900	2 39	3 19	17	29	1139	4·30	1·75
2000	2 50	3 34	16	27	1122	4·57	1·90
2100	3 2	3 50	15	25	1105	4·84	2·05
2200	3 14	4 7	14	23	1090	5·12	2·21
2300	3 26	4 24	13	22	1075	5·40	2·36
2400	3 38	4 42	12	20	1061	5·68	2·52
2500	3 50	5 1	11	19	1048	5·97	2·69
2600	4 3	5 20	11	18	1036	6·26	2·87
2700	4 16	5 40	10	17	1026	6·55	3·05
2800	4 29	6 1	9·5	16	1017	6·85	3·23
2900	4 42	6 23	9·0	15	1008	7·15	3·41
3000	4 56	6 45	8·4	14	999	7·45	3·59
3100	5 10	7 8	8·0	13	990	7·75	3·77
3200	5 24	7 31	7·6	13	981	8·06	3·96
3300	5 38	7 55	7·2	12	973	8·37	4·14
3400	5 53	8 19	6·8	11	964	8·68	4·32
3500	6 8	8 44	6·5	11	956	8·99	4·50
3600	6 24	9 9	6·2	10	947	9·30	4·67
3700	6 40	9 34	5·9	10	939	9·61	4·84
3800	6 56	10 0	5·7	9	931	9·93	
3900	7 12	10 26	5·4	9	923	10·25	
4000	7 28	10 52	5·2	9	916	10·55	
4100	7 45	11 19	5·0	8	909	10·9	
4200	8 2	11 46	4·8	8	902	11·2	
4300	8 19	12 13	4·6	8	894	11·5	
4400	8 36	12 41	4·4	7	887	11·9	
4500	8 53	13 9	4·3	7	879	12·2	
4600	9 10	13 37	4·1	7	872	12·5	
4700	9 28	14 6	4·0	7	865	12·9	
4800	9 46	14 35	3·8	6	858	13·2	
4900	10 4	15 4	3·7	6	852	13·6	
5000	10 22	15 34	3·5	6	845	13·9	

Note.—The accuracy on a vertical target is about equal to that with full charge, and consequently, owing to larger angle of descent, the accuracy on a horizontal target is somewhat superior.

Range Table for 6-inch B.L. Gun, Mark II.

Based on Practice of 13. 4. 83., 11. 5. 83., 19. 6. 83., 31. 12. 83., and 2. 4. 84.

Charge, 34 lb. P[a].
Projectile, weight, 100 lb.
Gravimetric density, $\frac{40 \cdot 6}{0 \cdot 633}$
Muzzle velocity, 1660 f.s.
Jump, 10 minutes.
Mounting, Armstrong, with E. O. C. compressor.

Range.	Elevation.		Angle of Descent.		Slope of Descent.	To hit an object 10 ft. high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	50 per cent. of rounds should fall within			Time of Flight.	Fuze Scale. Armstrong Medium and Concussion Fuze.
									Length.	Breadth.	Height.		
yds.	°	′	°	′	1 in	yds.	f.s.	ins.	yds.	yds.	feet	secs.	
0							1660	10·3					
100	0	8	0	6	573	955	1635	10·1	18	0·05	0·1	0·18	
200	0	8	0	13	264	461	1610	10·0	18	0·05	0·2	0·37	
300	0	12	0	20	172	286	1586	9·8	18	0·10	0·3	0·56	
400	0	17	0	27	127	212	1562	9·7	18	0·15	0·4	0·75	
500	0	23	0	34	101	169	1538	9·5	18	0·15	0·5	0·95	
600	0	29	0	42	82	136	1514	9·3	18	0·20	0·6	1·15	
700	0	36	0	49	70	117	1490	9·2	18	0·25	0·8	1·35	
800	0	43	0	57	60	101	1466	9·0	18	0·25	0·9	1·56	
900	0	50	1	5	53	88	1443	8·9	18	0·30	1·0	1·77	
1000	0	57	1	14	46	77	1420	8·7	18	0·35	1·2	1·98	
1100	1	4	1	23	41	69	1397	8·6	19	0·35	1·3	2·20	
1200	1	11	1	32	37	62	1375	8·4	19	0·40	1·5	2·42	
1300	1	18	1	42	34	56	1353	8·3	19	0·45	1·7	2·64	0·60
1400	1	26	1	52	31	51	1332	8·1	19	0·45	1·9	2·87	0·82
1500	1	34	2	2	28	47	1312	8·0	19	0·50	2·1	3·10	1·03
1600	1	42	2	13	26	43	1293	7·9	19	0·55	2·3	3·33	1·16
1700	1	50	2	24	24	40	1274	7·7	19	0·60	2·5	3·56	1·30
1800	1	59	2	35	22	37	1255	7·6	20	0·65	2·7	3·80	1·44
1900	2	8	2	47	21	34	1236	7·5	20	0·70	2·9	4·04	1·58
2000	2	17	2	59	19	32	1218	7·4	20	0·75	3·2	4·29	1·73
2100	2	26	3	12	18	30	1200	7·2	20	0·75	3·4	4·54	1·88
2200	2	35	3	25	17	28	1183	7·1	20	0·80	3·6	4·79	2·03
2300	2	45	3	38	16	26	1166	7·0	21	0·85	3·9	5·04	2·18
2400	2	55	3	52	15	25	1150	6·9	21	0·90	4·2	5·30	2·34
2500	3	5	4	6	14	23	1135	6·8	21	0·95	4·5	5·56	2·50
2600	3	15	4	21	13	22	1120	6·7	21	1·0	4·8	5·82	2·66
2700	3	25	4	36	12	21	1106	6·6	22	1·0	5·2	6·09	2·82
2800	3	36	4	51	12	20	1093	6·5	22	1·1	5·6	6·36	2·98
2900	3	47	5	7	11	19	1081	6·4	22	1·2	6·0	6·63	3·15
3000	3	58	5	23	11	18	1069	6·3	23	1·2	6·4	6·90	3·32
3100	4	9	5	40	10	17	1058	6·2	23	1·3	6·9	7·18	3·49
3200	4	20	5	57	9·6	16	1048	6·1	23	1·4	7·4	7·46	3·66
3300	4	31	6	15	9·1	15	1038	6·1	24	1·4	7·9	7·74	3·83
3400	4	43	6	33	8·7	15	1029	6·0	24	1·5	8·4	8·03	4·00
3500	4	55	6	51	8·3	14	1020	5·9	25	1·6	8·9	8·32	4·18
3600	5	7	7	10	8·0	13	1011	5·9	25	1·6	9·5	8·61	4·36
3700	5	19	7	29	7·6	13	1002	5·8	25	1·7	10·0	8·91	4·54
3800	5	32	7	48	7·3	12	994	5·8	25	1·8	11·0	9·21	4·72
3900	5	45	8	7	7·0	12	986	5·7	26	1·8	11·0	9·51	4·90
4000	5	58	8	27	6·7	11	978	5·7	27	1·9	12·0	9·81	
4100	6	11	8	47	6·5	11	971	5·6	27	2·0	12·0	10·1	

Range Table for 6-inch B.L. Gun, Mark II.—*continued.*

Range.	Elevation.		Angle of Descent.		Slope of Descent.	To hit an object 10 ft. high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	50 per cent. of rounds should fall within			Time of Flight.	Fuze scale, Armstrong Medium and Concussion Fuze.
									Length.	Breadth.	Height.		
4200	6	24	9	8	6·2	10	964	5·6	28	2·1	13	10·4	
4300	6	37	9	29	6·0	10	957	5·5	28	2·1	14	10·7	
4400	6	51	9	50	5·7	10	951	5·5	29	2·2	15	11·0	
4500	7	5	10	12	5·5	9	945	5·5	30	2·3	16	11·4	
4600	7	19	10	34	5·3	9	939	5·4	31	2·4	17	11·7	
4700	7	33	10	56	5·1	9	933	5·4	32	2·4	18	12·0	
4800	7	47	11	19	5·0	8	927	5·3	32	2·5	20	12·3	
4900	8	1	11	42	4·8	8	922	5·3	33	2·6	21	12·6	
5000	8	16	12	5	4·6	8	916	5.3	34	2·7	22	13·0	
5100	8	31	12	29	4·5	7	911	5·2				13·3	
5200	8	46	12	55	4·4	7	906	5·2				13·6	
5300	9	1	13	17	4·2	7	901	5·1				14·0	
5400	9	16	13	42	4·1	7	896	5·1				14·3	
5500	9	31	14	7	3·9	7	891	5·1				14·6	
5600	9	47	14	33	3·8	6	886	5·0				15·0	
5700	10	3	14	59	3·7	6	882	5·0				15·3	
5800	10	19	15	24	3·6	6	877	5·0				15·6	
5900	10	35	15	50	3·5	6	872	4·9				16·0	
6000	10	51	16	17	3·4	6	868	4·9				16·3	
6100	11	8	16	44	3·3	6	864	4·9				16·6	
6200	11	25	17	11	3·2	5	859	4·9				17·0	
6300	11	42	17	39	3·1	5	855	4·8				17·3	
6400	11	59	18	7	3·0	5	851	4·8				17·7	
6500	12	16	18	35	3·0	5	847	4·8				18·0	
6600	12	34	19	4	2·9	5	843	4·8				18·3	
6700	12	52	19	33	2·8	5	839	4·7				18·7	
6800	13	10	20	2	2·7	5	835	4·7				19·1	
6900	13	28	20	32	2·7	4	831	4·7				19·4	
7000	13	46	21	2	2·6	4	828	4·7				19·7	
7100	14	5	21	32	2·5	4	824	4·7				20·1	
7200	14	24	22	3	2·5	4	820	4·6				20·4	
7300	14	43	22	34	2·4	4	817	4·6				20·8	
7400	15	2	23	5	2·4	4	813	4·6				21·1	
7500	15	22	23	37	2·3	4	810	4·6				21·5	
7600	15	42	24	9	2·2	4	806	4·5				21·9	
7700	16	3	24	41	2·2	4	803	4·5				22·2	
7800	16	24	25	11	2·1	4	800	4·5				22·6	
7900	16	46	25	44	2·1	3	797	4·5				23·0	
8000	17	9	26	18	2·0	3	794	4·5				23·4	

Range Table for 6-inch B.L Gun, Mark II.

Based on Practice of 3. 7. 83.

Mounting, Vavasseur broadside.
Jump, 4 minutes.
Charge, 17 lb. P.², brand No. 218.
Projectile, weight 100 lb.
Muzzle velocity, 1133 f.s.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	50 per cent. of rounds should fall within			Time of Flight.	Fuze scale.—Armstrong medium fuze.
						Length.	Breadth.	Height.		
yards.	° ′	° ′	f.s.	yards.	yards.	yards.	yards.	yards.	secs.	
100	0 9	0 13	1117	38·5	0·14					
200	0 22	0 27	1103	37·9	0·29					
300	0 36	0 42	1089	37·8	0·43	10·0	0·09	0·10	0·80	
400	0 49	0 56	1076	36·8	0·58	10·0	0·13	0·14	1·07	
500	1 2	1 11	1064	36·2	0·72	10·1	0·17	0·19	1·34	
600	1 16	1 25	1053	35·7	0·87	10·2	0·21	0·24	1·63	
700	1 30	1 40	1043	35·1	1·01	10·3	0·25	0·30	1·90	
800	1 44	1 55	1034	34·6	1·16	10·5	0·29	0·36	2·17	0·34
900	1 58	2 11	1025	34·1	1·31	10·7	0·34	0·42	2·45	0·50
1000	2 13	2 27	1016	33·6	1·45	11·0	0·39	0·49	2·73	0·67
1100	2 28	2 44	1007	33·1	1·60	11·2	0·44	0·57	3·02	0·85
1200	2 44	3 2	999	32·6	1·74	11·5	0·49	0·66	3·32	1·02
1300	3 0	3 20	991	32·2	1·89	11·8	0·54	0·75	3·63	1·20
1400	3 16	3 39	984	31·7	2·03	13·2	0·59	0·85	3·94	1·37
1500	3 32	3 58	977	31·2	2·18	13·8	0·64	0·97	4·25	1·53
1600	3 48	4 17	969	30·8	2·32	14·5	0·70	1·10	4·56	1·70
1700	4 4	4 37	961	30·3	2·47	15·3	0·75	1·25	4·87	1·86
1800	4 21	4 58	954	29·9	2·61	16·1	0·81	1·42	5·19	2·02
1900	4 38	5 19	946	29·5	2·76	17·0	0·97	1·60	5·51	2·19
2000	4 55	5 41	939	29·1	2·91	18·0	1·03	1·79	5·83	2·35
2100	5 12	6 3	932	28·7	3·05	19·2	1·09	2·0	6·16	2·53
2200	5 29	6 25	925	28·3	3·20	20·5	1·15	2·24	6·49	2·72
2300	5 46	6 48	918	27·9	3·34	21·9	1·21	2·52	6·83	2·91
2400	6 4	7 11	911	27·6	3·49	23·4	1·27	2·90	7·17	3·10
2500	6 22	7 35	905	27·2	3·63	25·0	1·34	3·30	7·51	3·29
2600	6 40	7 59	898	26·9	3·78	26·7	1·40	3·74	7·86	3·49
2700	6 59	8 23	892	26·5	3·92	28·5	1·46	4·22	8·21	3·68
2800	7 18	8 48	885	26·1	4·07	30·3	1·53	4·73	8·56	3·87
2900	7 37	9 13	879	25·7	4·21	32·2	1·60	5·26	8·92	4·06
3000	7 56	9 39	873	25·4	4·36	34·1	1·67	5·80	9·28	4·26
3100	8 16	10 6	867	25·0	4·51	35·8	1·74	6·38	9·64	4·46
3200	8 36	10 34	861	24·6	4·65	37·4	1·81	6·98	10·00	4·66
3300	8 56	11 3	855	24·3	4·80	38·8	1·88	7·60	10·37	4·86
3400	9 17	11 34	849	23·9	4·94	40·0	1·96	8·23	10·74	
3500	9 38	12 6	844	23·5	5·09	41·1	2·04	8·86	11·11	
3600	10 0	12 39	838	23·1	5·23	42·1	2·12	9·50	11·49	
3700	10 22	13 12	833	22·7	5·38	43·0	2·21	10·16	11·86	
3800	10 45	13 41	827	22·3	5·52	43·9	2·30	10·84	12·23	
3900	11 8	14 21	822	21·9	5·67	44·7	2·39	11·54	12·60	
4000	11 32	14 56	817	21·5	5·81	45·5	2·48	12·26	12·96	

Range Table for 6-inch B.L. Gun, Mark III.

Based on Practice of 28. 2. to 9. 3. 82., 16. 3. 82., 24. and 27. 3. 82., 22. 6. 82., 12. 7. 82., 22. 7. 82., 17. and 18. 1. 83., 3. 12. 83., 22. 1. and 1. 2. 84., and 20. 2. 84.

Charge, 42 lb. P.[2]
Projectile, 100 lb.
Muzzle velocity, 1850 f.s.*
Mounting, E. O. C.†
Jump, 7 minutes.†

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within			Time of Flight.	Fuze scale.—Armstrong medium time and concussion fuze.	Penetration of wrought iron.
						Length.	Breadth.	Height.			
yds.	° ′	° ′	f.s.	1 in	yds.	yds.	yds.	ft.	secs.	ins.	ins.
100		0 5	1823	688	1146	18	0·05	0·1	0·16		11·4
200	0 3	0 11	1796	812	520	18	0·05	0·2	0·33		11·2
300	0 8	0 17	1770	202	337	18	0·1	0·3	0·50		11·0
400	0 14	0 23	1745	149	249	18	0·1	0·4	0·66		10·9
500	0 19	0 29	1720	119	198	18	0·15	0·5	0·83		10·7
600	0 25	0 36	1694	95	159	18	0·2	0·6	1·0		10·5
700	0 30	0 42	1669	82	136	18	0·2	0·7	1·18		10·4
800	0 36	0 48	1643	72	119	18	0·25	0·8	1·35		10·2
900	0 41	0 55	1618	62	106	18	0·25	0·9	1·52		10·0
1000	0 47	1 1	1594	56	94	18	0·3	1·0	1·70		9·8
1100	0 53	1 8	1569	51	84	18	0·35	1·1	1·89		9·7
1200	0 59	1 15	1545	46	76	18	0·4	1·2	2·08		9·5
1300	1 5	1 23	1521	41	69	18	0·4	1·4	2·27	0·50	9·4
1400	1 11	1 31	1497	38	63	18	0·45	1·5	2·46	0·72	9·2
1500	1 18	1 39	1473	35	58	18	0·5	1·6	2·65	0·91	9·1
1600	1 24	1 48	1450	32	53	18	0·5	1·7	2·85	1·07	8·9
1700	1 31	1 57	1427	29	49	18	0·55	1·9	3·05	1·21	8·7
1800	1 37	2 6	1404	27	45	18	0·6	2·0	3·26	1·35	8·6
1900	1 44	2 16	1381	25	42	18	0·65	2·2	3·47	1·49	8·4
2000	1 51	2 26	1359	24	39	19	0·65	2·4	3·68	1·64	8·3
2100	1 58	2 36	1338	22	37	19	0·7	2·6	3·90	1·78	8·1
2200	2 5	2 46	1316	21	35	19	0·75	2·8	4·12	1·93	8·0
2300	2 13	2 57	1295	20	33	19	0·8	3·0	4·34	2·08	7·9
2400	2 20	3 7	1276	18	31	19	0·85	3·2	4·57	2·23	7·8
2500	2 28	3 18	1256	17	29	20	0·9	3·5	4·80	2·37	7·6
2600	2 35	3 28	1238	16	27	20	0·95	3·7	5·04	2·52	7·5
2700	2 44	3 39	1220	16	26	20	1·0	4·0	5·28	2·67	7·4
2800	2 52	3 51	1203	15	25	21	1·0	4·3	5·52	2·83	7·3
2900	3 0	4 3	1186	14	24	21	1·1	4·5	5·76	2·99	7·1
3000	3 9	4 15	1170	13	22	22	1·1	4·9	6·01	3·15	7·0
3100	3 17	4 28	1154	13	21	22	1·1	5·2	6·26	3·30	6·9
3200	3 26	4 41	1139	12	20	23	1·20	5·6	6·51	3·45	6·8
3300	3 35	4 55	1124	12	19	23	1·2	6	6·77	3·60	6·7
3400	3 45	5 9	1110	11	18	24	1·3	6·5	7·02	3·76	6·6
3500	3 55	5 24	1096	11	18	24	1·3	7	7·28	3·92	6·5
3600	4 5	5 39	1083	10	17	24	1·4	7·5	7·55	4·09	6·4
3700	4 14	5 54	1071	9·7	16	25	1·4	8	7·82	4·26	6·3
3800	4 24	6 9	1059	9·3	15	25	1·5	8·5	8·09	4·43	6·2
3900	4 35	6 25	1048	8·9	15	26	1·5	9	8·37	4·60	6·1
4000	4 45	6 42	1037	8·5	14	26	1·6	9·5	8·65	4·77	6·0
4100	4 56	6 59	1029	8·2	14	26	1·7	10	8·94		
4200	5 7	7 16	1022	7·8	13	27	1·7	10	9·23		5·9
4300	5 18	7 34	1015	7·5	13	27	1·8	11	9·53		
4400	5 29	7 53	1008	7·2	12	28	1·8	12	9·82		
4500	5 40	8 12	1001	6·9	12	28	1·9	12	10·1		5·8
4600	5 52	8 31	994	6·7	11	28	1·9	13	10·4		
4700	6 4	8 50	987	6·4	11	29	2·0	14	10·7		5·7
4800	6 15	9 11	980	6·2	10	29	2·1	14	11·0		
4900	6 27	9 32	973	6·0	10	30	2·1	15	11·3		
5000	6 39	9 52	967	5·8	10	30	2·2	16	11·6		5·6
5100	6 52	10 12	961	5·6	9	31	2·3	17	11·9		
5200	7 4	10 32	955	5·4	9	31	2,3	17	12·2		5·5
5300	7 16	10 52	949	5·2	9	32	2·4	18	12·6		

RANGE TABLE FOR 6-INCH B L. GUN, MARK III.—*continued.*

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within			Time of Flight.	Fuse scale.—Armstrong medium time and concussion fuse.	Penetration of wrought iron.
						Length.	Breadth.	Height.			
yds.	° ′	° ′	f.s.	1 in	yds.	yds.	yds.	ft.	secs.	ins.	ins.
5400	7 28	11 12	943	5·1	8	32	2·5	19	12·9		
5500	7 41	11 32	937	4·9	8	33	2·6	20	13·2		5·4
5600	7 54	11 53	932	4·8	8	33	2·6	21	13·5		
5700	8 7	12 13	926	4·6	8	34	2·7	22	13·9		
5800	8 20	12 34	921	4·5	7	35	2·8	23	14·2		5·3
5900	8 33	12 55	915	4·4	7	35	2·9	24	14·5		
6000	8 46	13 16	910	4·2	7	36	3·0	26	14·8		
6100	8 59	13 38	905	4·1	7				15·2		5·2
6200	9 12	14 0	900	4·0	7				15·5		
6300	9 26	14 22	895	3·9	7				15·8		
6400	9 39	14 45	891	3·8	6				16·2		5·1
6500	9 53	15 8	886	3·7	6				16·5		
6600	10 7	15 31	882	3·6	6				16·8		
6700	10 21	15 54	877	3·5	6				17·2		5·0
6800	10 36	16 18	873	3·4	6				17·5		
6900	10 51	16 42	869	3·3	6				17·8		
7000	11 7	17 6	865	3·3	5				18·2		4·9
7100	11 22	17 29	861	3·2	5				18·5		
7200	11 38	17 53	857	3·1	5				18·9		
7300	11 53	18 17	853	3·0	5				19·2		
7400	12 9	18 41	850	3·0	5				19·6		
7500	12 25	19 6	846	2·9	5				19·9		4·8
7600	12 41	19 31	843	2·8	5				20·3		
7700	12 57	19 56	839	2·8	5				20·6		
7800	13 14	20 22	836	2·7	4				21·0		
7900	13 31	20 48	832	2·6	4				21·3		
8000	13 48	21 15	829	2·6	4				21·7		4·7
8100	14 5	21 42	826	2·5	4				22·0		
8200	14 22	22 9	824	2·5	4				22·4		
8300	14 39	22 37	822	2·4	4				22·7		
8400	14 56	23 6	820	2·3	4				23·1		4·6
8500	15 14	23 35	818	2·3	4				23·5		
8600	15 32	24 4	815	2·2	4				23·8		
8700	15 50	24 33	813	2·2	4				24·2		
8800	16 8	25 2	811	2·1	4				24·6		
8900	16 26	25 31	809	2·1	3				24·9		
9000	16 45	26 0	807	2·0	3				25·3		4·5
9100	17 4	26 30	805	2·0	3				25·7		
9200	17 23	27 0	803	2·0	3				26·1		
9300	17 42	27 31	802	1·9	3				26·5		
9400	18 2	28 1	800	1·9	3				26·9		
9500	18 21	28 32	799	1·8	3				27·4		
9600	18 41	29 3	797	1·8	3				27·8		
9700	19 1	29 34	796	1·8	3				28·2		
9800	19 21	30 6	794	1·7	3				28·6		
9900	19 42	30 38	793	1·7	3				29·0		
10000	20 3	31 10	792	1·6	3				29·5		4·4

* The muzzle velocity has been found to vary from 1893 to 1830 f.s., according to the brand of powder used.

An increase of 100 f.s. in the muzzle velocity increases the range at ordinary ranges about 8 per cent.

† Guns on Vavasseur mountings will very probably require 5 minutes' more elevation than is given in this table owing to the reduced jump.

Range Table for 6-inch B.L. Gun, Mark III.

Based on Practice of 3. 12. 83. and 29. 1. 84.

Charge, 21 lb. P.^{2}
Projectile, weight 100 lb.
Mounting E. O. C.
Jump, 3 minutes.
Muzzle velocity, 1260 f.s.*

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within			Time of Flight.	Fuse Scale.—Armstrong medium time and concussion fuze.
						Length.	Breadth.	Height.		
yds.	° ′	° ′	f.s.	1 in	yds.	yds.	yds.	ft.	secs.	
100	0 8	0 12	1244	286	477	10	0·1	0·1	0·25	
200	0 19	0 23	1228	144	236	10	0·1	0·2	0·50	
300	0 30	0 35	1212	98	164	10	0·1	0·3	0·75	
400	0 42	0 48	1196	72	119	10	0·1	0·4	1·01	
500	0 54	1 1	1180	56	94	10	0·2	0·5	1·26	
600	1 5	1 14	1164	46	77	11	0·2	0·7	1·52	
700	1 17	1 27	1148	39	66	11	0·2	0·8	1·78	
800	1 29	1 41	1133	34	57	11	0·3	1·0	2·04	
900	1 41	1 55	1118	30	50	11	0·3	1·1	2·30	0·70
1000	1 54	2 10	1104	26	44	12	0·4	1·3	2·56	0·90
1100	2 6	2 24	1089	24	40	12	0·4	1·4	2·83	1·08
1200	2 19	2 39	1076	22	36	12	0·5	1·6	3·10	1·24
1300	2 32	2 54	1065	20	33	13	0·5	1·8	3·37	1·39
1400	2 45	3 9	1054	18	30	13	0·6	2·1	3·64	1·55
1500	2 58	3 25	1043	17	28	13	0·6	2·4	3·91	1·70
1600	3 12	3 42	1034	15	26	14	0·7	2·7	4·19	1·85
1700	3 25	3 59	1025	14	24	14	0·7	3·0	4·47	2·0
1800	3 39	4 17	1017	13	22	15	0·8	3·4	4·75	2·16
1900	3 54	4 35	1009	12	21	15	0·9	3·8	5·03	2·32
2000	4 9	4 54	1001	12	19	16	0·9	4·2	5·32	2·49
2100	4 24	5 13	993	11	18	16	1·0	4·6	5·61	2·66
2200	4 40	5 33	985	10	17	17	1·0	5·0	5·90	2·83
2300	4 55	5 53	977	9·7	16	18	1·1	5·5	6·19	3·0
2400	5 11	6 14	970	9·2	15	18	1·1	5·9	6·49	3·17
2500	5 27	6 34	962	8·7	14	19	1·2	6·4	6·79	3·35
2600	5 43	6 55	955	8·2	14	20	1·3	7·0	7·09	3·53
2700	5 59	7 17	947	7·8	13	20	1·3	7·7	7·40	3·71
2800	6 16	7 39	940	7·4	12	21	1·4	8·5	7·71	3·89
2900	6 32	8 1	933	7·1	12	21	1·4	9·2	8·02	4·07
3000	6 49	8 23	926	6·8	11	22	1·5	10	8·34	4·25
3100	7 7	8 46	919	6·5	11				8·66	4·43
3200	7 24	9 9	912	6·2	10				8·99	4·61
3300	7 42	9 32	906	6·0	10				9·32	4·78
3400	8 0	9 57	899	5·7	10				9·66	4·95
3500	8 18	10 22	893	5·5	9				10·0	
3600	8 36	10 47	887	5·3	9				10·35	
3700	8 55	11 12	880	5·1	8				10·70	
3800	9 13	11 37	874	4·9	8				11·06	
3900	9 32	12 2	868	4·7	8				11·43	
4000	9 51	12 28	862	4·5	8				11·80	

* The velocity will probably vary from about 1230 to 1290 f.s. according to the brand of powder used. An increase of 100 f.s. in the velocity increases the range at ordinary ranges about 11 per cent.

RANGE TABLE FOR 8-INCH B.L., MARKS I. AND III.

Based on Practice of 30. 1. 84., 7. 2. 84., 19. 2. 84., 12. 3. 84., 29. 7. 84.

Charge, 100 lb. prism[1], Black.
Gravimetric density, $\frac{30\cdot5}{0\cdot907}$.
Projectile, 210 lb.
Mounting, Elswick experimental (modified in R.C.D.).
Muzzle velocity, 1953 f.s.*
Jump, *nil*.†

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	50 per cent. of rounds should fall within			Time of Flight.	Fuze Scale.—Armstrong medium time and concussion fuze.	Penetration, wrought-iron.
						Length.	Breadth.	Height.			
yds.	° ′	° ′	f.s.	yds.	yds.	yds.	yds.	yds.	secs.		ins.
0	†										
100	0 4	0 4	1930	119	0·14	20	0·02	0·02	0·15		15·3
200	0 8	0 8	1906	117	0·29	20	0·05	0·05	0·30		15·1
300	0 13	0 13	1882	115	0·43	20	0·08	0·08	0·46		14·9
400	0 17	0 18	1859	112	0·58	20	0·11	0·11	0·62		14·7
500	0 22	0 24	1836	110	0·72	20	0·14	0·14	0·78		14·5
600	0 27	0 29	1814	108	0·87	20	0·16	0·17	0·94		14·3
700	0 31	0 34	1792	106	1·01	20	0·19	0·20	1·11		14·1
800	0 36	0 40	1769	104	1·16	20	0·22	0·23	1·28		13·9
900	0 41	0 45	1747	102	1·31	20	0·25	0·26	1·45		13·7
1000	0 46	0 50	1725	100	1·45	20	0·28	0·29	1·63		13·5
1100	0 51	0 56	1704	98·1	1·60	20	0·32	0·33	1·81	0·50	13·4
1200	0 56	1 2	1682	96·2	1·74	20	0·35	0·36	1·99	0·68	13·2
1300	1 1	1 9	1661	94·4	1·89	20	0·38	0·40	2·18	0·85	13·0
1400	1 6	1 15	1640	92·6	2·03	20	0·42	0·44	2·36	1·00	12·8
1500	1 12	1 22	1619	90·9	2·18	20	0·45	0·48	2·55	1·13	12·6
1600	1 18	1 29	1598	89·2	2·32	20	0·48	0·52	2·74	1·26	12·4
1700	1 23	1 36	1577	87·5	2·47	20	0·52	0·56	2·93	1·39	12·2
1800	1 29	1 43	1557	85·9	2·61	20	0·55	0·61	3·12	1·52	12·1
1900	1 36	1 51	1537	84·3	2·76	20	0·59	0·66	3·32	1·65	11·9
2000	1 42	2 0	1517	82·7	2·91	20	0·62	0·70	3·52	1·78	11·7
2100	1 48	2 9	1498	81·1	3·05	20	0·66	0·75	3·72	1·91	11·6
2200	1 54	2 18	1478	79·6	3·20	20	0·70	0·80	3·93	2·05	11·4
2300	2 0	2 27	1459	78·1	3·34	20	0·74	0·86	4·13	2·18	11·3
2400	2 6	2 37	1439	76·6	3·49	20	0·78	0·92	4·34	2·31	11·1
2500	2 13	2 46	1420	75·2	3·63	20·1	0·83	0·98	4·55	2·45	10·9
2600	2 19	2 56	1400	73·8	3·78	20·2	0·87	1·04	4·76	2·58	10·7
2700	2 26	3 6	1381	72·4	3·92	20·4	0·92	1·11	4·97	2·71	10·6
2800	2 33	3 16	1362	71·1	4·07	20·6	0·96	1·18	5·19	2·85	10·4
2900	2 40	3 26	1344	69·8	4·21	20·8	1·01	1·25	5·41	2·99	10·3
3000	2 47	3 37	1326	68·5	4·36	21·0	1·06	1·33	5·63	3·12	10·1
3100	2 54	3 48	1309	67·3	4·51	21·2	1·10	1·41	5·86	3·26	10·0
3200	3 2	3 59	1292	66·1	4·65	21·5	1·15	1·50	6·09	3·40	9·8
3300	3 9	4 12	1276	65·0	4·80	21·8	1·20	1·60	6·32	3·53	9·7
3400	3 17	4 24	1260	63·8	4·94	22·1	1·25	1·71	6·56	3·66	9·5
3500	3 25	4 36	1245	62·6	5·09	22·5	1·31	1·83	6·80	3·80	9·4

* The muzzle velocity may be expected to vary from 1925 to 1975 f.s., according to the brand of powder used. An increase of 100 f.s. in the muzzle velocity increases the range at ordinary ranges about 8¼ per cent.

† The jump of the gun may very probably be different on another mounting, which would of course affect the elevation.

RANGE TABLE FOR 8-INCH B L., MARKS I. AND III.—*continued.*

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	5 minutes' elevation increases or decreases the Range by	5 minutes will alter point of impact vertically or laterally at each Range	50 per cent. of rounds should fall within			Time of Flight.	Fuze Scale.—Armstrong medium time and concussion fuze.	Penetration, wrought-iron.
						Length.	Breadth.	Height.			
yds.	° ′	° ′	f.s.	yds.	yds.	yds.	yds.	yds.	secs.		ins.
3600	3 33	4 49	1230	61·5	5·23	22·9	1·36	1·96	7·04	3·94	9·2
3700	3 41	5 1	1216	60·4	5·38	23·4	1·42	2·09	7·29	4·08	9·1
3800	3 49	5 15	1202	59·4	5·52	23·9	1·47	2·23	7·53	4·22	9·0
3900	3 58	5 30	1188	58·4	5·67	24·5	1·53	2·37	7·78	4·37	8·9
4000	4 7	5 44	1174	57·4	5·81	25·0	1·58	2·52	8·03	4·52	8·8
4100	4 15	5 58	1161	56·5	5·96	25·5	1·64	2·69	8·27	4·67	
4200	4 24	6 13	1148	55·6	6·11	26·1	1·69	2·87	8·52	4·82	
4300	4 33	6 27	1135	54·8	6·25	26·7	1·75	3·06	8·77		8·5
4400	4 42	6 42	1123	54·0	6·40	27·4	1·81	3·27	9·02		
4500	4 51	6 56	1110	53·2	6·54	28·2	1·87	3·49	9·28		
4600	5 0	7 11	1098	52·5	6·69	29·0	1·93	3·71	9·54		
4700	5 10	7 26	1086	51·8	6·83	29·9	2·00	3·94	9·81		
4800	5 19	7 41	1075	51·1	6·98	30·8	2·06	4·18	10·1		8·0
4900	5 29	7 56	1064	50·4	7·13	31·7	2·13	4·42	10·4		
5000	5 39	8 12	1054	49·8	7·27	32·5	2·19	4·67	10·7		
5100	5 49	8 28	1045	49·1	7·42	33·3	2·26	4·93	10·9		
5200	6 0	8 45	1036	48·5	7·56	34·0	2·33	5·20	11·2		
5300	6 11	9 2	1028	47·8	7·71	34·7	2·39	5·49	11·5		
5400	6 22	9 20	1021	47·2	7·85	35·3	2·46	5·80	11·8		7·5
5500	6 33	9 38	1015	46·6	8·00	36·0	2·53	6·11	12·1		
5600	6 45	9 57	1009	46·0	8·14	36·6	2·60	6·43	12·4		
5700	6 57	10 16	1003	45·4	8·29	37·3	2·68	6·76	12·6		
5800	7 9	10 35	997	44·8	8·43	37·9	2·75	7·11	12·9		
5900	7 20	10 55	990	44·2	8·58	38·5	2·82	7·47	13·2		
6000	7 32	11 15	984	43·7	8·73	39·0	2·90	7·84	13·5		
6100	7 43	11 35	978	43·1	8·87				13·8		
6200	7 55	11 56	971	42·6	9·01				14·2		
6300	8 7	12 17	965	42·0	9·16				14·5		7·0
6400	8 19	12 38	958	41·5	9·30				14·8		
6500	8 31	13 9	952	40·9	9·45				15·1		
6600	8 44	13 21	946	40·4	9·60				15·4		
6700	8 56	13 43	940	39·8	9·74				15·7		
6800	9 9	14 5	934	39·3	9·89				16·0		
6900	9 22	14 28	928	38·7	10·03				16·4		
7000	9 35	14 51	923	38·2	10·18				16·7		
7100	9 48	15 14	917	37·7	10·32				17·0		
7200	10 1	15 38	911	37·2	10·46				17·3		
7300	10 14	16 3	906	36·7	10·60				17·6		6·5
7400	10 28	16 28	900	36·2	10·75				17·9		
7500	10 42	16 54	894	35·7	10·89				18·2		
7600	10 56	17 20	889	35·3	11·04				18·6		
7700	11 11	17 46	883	34·9	11·19				18·9		
7800	11 26	18 13	878	34·5	11·34				19·3		
7900	11 41	18 40	873	34·1	11·48				19·6		
8000	11 56	19 7	867	33·7	11·63				20·0		

Range Table for 8-inch B.L., Marks I. and III.

Based on Practice of 19. 2. 84.

Charge, 50 lb. Prism[1], Black. Gravimetric density, $\frac{61\cdot0}{0\cdot454}$.
Projectile, 210 lb.
Mounting, Elswick experimental (modified in R.C.D.).
Muzzle velocity, 1300 f.s.
Jump, 3 minutes.

Range.	Elevation.		Angle of Descent.		Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Time of Flight.	Fuze scale. Armstrong medium time and concussion fuze.
yards.	°	′	°	′	f.s.	1 in	yards.	seconds.	
0									
100	0	6	0	10	1284	344	573	0·22	
200	0	16	0	21	1268	164	273	0·45	
300	0	27	0	32	1253	107	179	0·68	
400	0	38	0	44	1238	78	130	0·91	
500	0	47	0	56	1223	61	102	1·15	
600	1	1	1	8	1209	51	84	1·39	
700	1	12	1	21	1195	42	71	1·63	
800	1	24	1	34	1181	37	61	1·88	
900	1	36	1	47	1167	32	54	2·13	0·45
1000	1	48	2	1	1154	28	48	2·38	0·72
1100	2	0	2	15	1141	25	43	2·64	1·00
1200	2	12	2	29	1128	23	38	2·90	1·16
1300	2	24	2	43	1116	21	35	3·16	1·31
1400	2	37	2	58	1104	19	32	3·42	1·46
1500	2	50	3	13	1092	18	30	3·69	1·62
1600	3	2	3	28	1081	17	28	3·96	1·77
1700	3	15	3	44	1070	15	26	4·23	1·92
1800	3	28	4	0	1059	14	24	4·50	2·08
1900	3	41	4	16	1049	13	22	4·78	2·24
2000	3	55	4	33	1040	13	21	5·06	2·40
2100	4	9	4	50	1032	12	20	5·34	2·56
2200	4	23	5	8	1024	11	19	5·62	2·72
2300	4	38	5	26	1017	10	18	5·91	2·88
2400	4	52	5	45	1010	9·9	17	6·20	3·05
2500	5	7	6	4	1003	9·4	16	6·49	3·22
2600	5	22	6	24	997	8·9	15	6·78	3·39
2700	5	37	6	44	990	8·5	14	7·08	3·56
2800	5	52	7	5	984	8·1	13	7·38	3·74
2900	6	7	7	26	978	7·7	13	7·68	3·91
3000	6	23	7	47	973	7·3	12	7·98	4·09
3100	6	39	8	9	967	7·0	12	8·28	4·27
3200	6	55	8	31	960	6·7	11	8·59	4·45
3300	7	11	8	54	954	6·4	11	8·90	4·63
3400	7	28	9	17	948	6·1	10	9·21	4·81
3500	7	45	9	41	942	5·9	10	9·52	
3600	8	2	10	6	936	5·6	9	9·83	
3700	8	19	10	31	930	5·4	9	10·15	
3800	8	37	10	57	924	5·2	9	10·47	
3900	8	55	11	23	918	5·0	8	10·79	
4000	9	13	11	50	913	4·8	8	11·21	

Range Table for 8-inch B.L., Marks II. and IV.

Based on Practice of 20. and 22. 11. 83.

Charge 100 lb. Prism[1], Black. Gravimetric density, $\frac{30 \cdot 5}{0 \cdot 907}$.
Projectile, 210 lb.
Mounting, Elswick experimental (modified in R.C.D.).
Muzzle velocity, 2030 f.s.*
Jump, *nil*.

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within			Time of Flight.	Fuze scale.—Armstrong medium time and concussion fuze.	Penetration, wrought-iron.
						Length.	Breadth.	Height.			
yds.	° ′	° ′	f.s.	1 in	yds.	yds.	yds.	feet.	secs.		inches.
0											
100	0 4	0 4	2004	859	1432	20	0·02	0·1	0·14		16·0
200	0 8	0 8	1979	430	716	20	0·05	0·1	0·28		15·7
300	0 12	0 13	1954	264	441	20	0·08	0·2	0·43		15·5
400	0 16	0 17	1930	202	334	20	0·11	0·3	0·58		15·3
500	0 21	0 22	1906	156	260	20	0·14	0·4	0·73		15·1
600	0 25	0 27	1882	127	212	20	0·16	0·5	0·89		14·9
700	0 29	0 31	1859	111	185	20	0·19	0·6	1·05		14·7
800	0 33	0 36	1836	95	159	20	0·22	0·6	1·21		14·5
900	0 37	0 41	1814	84	140	20	0·25	0·7	1·37		14·3
1000	0 42	0 46	1792	75	125	20	0·28	0·8	1·54		14·1
1100	0 47	0 52	1769	66	110	20	0·32	0·9	1·71	0·40	13·9
1200	0 52	0 58	1747	59	99	20	0·35	1·0	1·88	0·59	13·7
1300	0 57	1 4	1725	54	90	20	0·38	1·1	2·06	0·76	13·5
1400	1 1	1 9	1704	50	83	20	0·42	1·2	2·24	0·91	13·4
1500	1 6	1 15	1682	46	76	20	0·45	1·3	2·42	1·03	13·2
1600	1 11	1 22	1661	42	70	20	0·48	1·5	2·61	1·16	13·0
1700	1 17	1 29	1640	39	65	20	0·52	1·6	2·79	1·29	12·8
1800	1 22	1 36	1619	36	60	20	0·55	1·7	2·98	1·43	12·6
1900	1 28	1 44	1598	33	55	20	0·59	1·8	3·17	1·56	12·4
2000	1 34	1 52	1577	31	51	20	0·62	2·0	3·36	1·70	12·2
2100	1 40	2 0	1557	29	47	20	0·66	2·1	3·55	1·83	12·1
2200	1 46	2 9	1537	27	44	20	0·70	2·3	3·75	1·96	11·9
2300	1 51	2 18	1517	25	41	20	0·74	2·4	3·95	2·09	11·7
2400	1 57	2 27	1498	23	39	20	0·78	2·6	4·15	2·22	11·6
2500	2 3	2 37	1478	22	36	20	0·83	2·8	4·36	2·35	11·4
2600	2 9	2 46	1459	21	34	20	0·87	2·9	4·56	2·48	11·3
2700	2 16	2 56	1439	20	33	20	0·92	3·1	4·77	2·61	11·1
2800	2 22	3 5	1420	19	31	21	0·96	3·3	4·98	2·75	10·9
2900	2 29	3 15	1400	18	29	21	1·01	3·5	5·19	3·88	10·7
3000	2 36	3 25	1381	17	28	21	1·06	3·8	5·40	3·02	10·6
3100	2 43	3 36	1362	16	26	21	1·10	4·0	5·62	3·15	10·4
3200	2 50	3 47	1344	15	25	21	1·15	4·3	5·84	3·29	10·3
3300	2 57	3 59	1326	14	24	22	1·20	4·5	6·06	3·43	10·1
3400	3 5	4 11	1309	14	23	22	1·25	4·8	6·29	3·56	10·0
3500	3 12	4 23	1292	13	22	22	1·31	5·2	6·52	3·70	9·8
3600	3 20	4 35	1276	12	21	23	1·36	5·5	6·75	3·84	9·7
3700	3 27	4 47	1260	12	20	23	1·42	5·9	6·99	3·98	9·5
3800	3 35	4 59	1245	11	19	24	1·47	6·3	7·23	4·12	9·4
3900	3 42	5 11	1230	11	18	24	1·53	6·7	7·47	4·27	9·2

RANGE TABLE FOR 8-INCH B.L., MARKS II. AND IV.—*continued.*

Range.	Elevation.	Angle of Descent.	Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	50 per cent. of rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Fuse scale.—Armstrong medium time and concussion fuse.	Penetration, wrought-iron.
yds.	° ′	° ′	f.s.	1 in	yds.	yds.	yds.	feet.	secs.		inches.
4000	3 49	5 24	1216	11	17	25	1·58	7·1	7·72	4·42	9·1
4100	3 57	5 37	1202	10	17	25	1·64	7·5	7·96	4·57	9·0
4200	4 5	5 50	1188	9·8	16	26	1·69	8·0	8·21	4·72	
4300	4 13	6 3	1174	9·3	16	26	1·75	8·5	8·46	4·87	
4400	4 21	6 17	1161	9·1	15	27	1·81	9·0	8·70		
4500	4 29	6 30	1148	8·8	15	28	1·87	9·6	8·95		
4600	4 38	6 44	1135	8·5	14	29	1·93	10	9·20		8·5
4700	4 46	6 58	1123	8·2	14	29	2·00	11	9·45		
4800	4 55	7 12	1110	7·9	13	30	2·06	11	9·71		
4900	5 4	7 26	1098	7·7	13	31	2·13	12	9·97		
5000	5 13	7 40	1086	7·4	12	32	2·19	13	10·24		
5100	5 22	7 55	1075	7·2	12	33	2·26	14	10·5		8·0
5200	5 31	8 10	1064	7·0	12	34	2·33	14	10·8		
5300	5 41	8 25	1054	6·8	11	34	2·39	15	11·2		
5400	5 50	8 40	1045	6·6	11	35	2·46	16	11·4		
5500	6 0	8 56	1036	6·4	11	36	2·53	17	11·7		
5600	6 10	9 12	1028	6·2	10	36	2·60	18	12·0		
5700	6 20	9 28	1021	6·0	10	37	2·68	18	12·2		7·5
5800	6 30	9 45	1015	5·8	10	37	2·75	19	12·5		
5900	6 40	10 2	1009	5·7	9	38	2·82	20	12·8		
6000	6 51	10 19	1003	5·5	9	38	2·90	21	13·0		
6100	7 1	10 36	997	5·3	9				13·3		
6200	7 12	10 54	990	5·2	9				13·6		
6300	7 22	11 12	984	5·1	8				13·9		
6400	7 33	11 30	978	4·9	8				14·3		
6500	7 44	11 48	971	4·8	8				14·6		
6600	7 55	12 8	965	4·7	8				14·9		7·0
6700	8 6	12 27	958	4·5	8				15·2		
6800	8 17	12 46	952	4·4	7				15·5		
6900	8 29	13 6	946	4·3	7				15·8		
7000	8 41	13 26	940	4·2	7				16·1		
7100	8 52	13 46	934	4·1	7				16·4		
7200	9 4	14 7	928	4·0	7				16·8		
7300	9 16	14 28	923	3·9	6				17·1		
7400	9 28	14 49	917	3·8	6				17·4		
7500	9 40	15 11	911	3·7	6				17·7		
7600	9 52	15 33	906	3·6	6				18·0		6·5
7700	10 5	15 55	900	3·5	6				18·3		
7800	10 18	16 17	894	3·4	6				18·6		
7900	10 31	16 40	889	3·3	6				19·0		
8000	10 44	17 8	883	3·3	5				19·3		

* The muzzle velocity may be expected to vary from 1995 to 2045 f.s., according to brand of powder used. An increase of 100 f.s. in the muzzle velocity increases the range at ordinary ranges about 8½ per cent.

Range Table for 8-inch B.L., Marks II. and IV.

Based on Calculation.

Charge, 50 lb. Prism[1], Black. Gravimetric density, $\frac{61 \cdot 0}{0 \cdot 454}$.

Projectile, 210 lb.

Mounting, Elswick experimental (modified in R.C.D.).

Muzzle velocity, 1350 f.s.

Jump, 3 minutes.

Range.	Elevation.		Angle of Descent.		Remaining Velocity.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Time of Flight.	Fuze scale. Armstrong medium time and concussion fuze.
yards.	°	′	°	′	f.s.	1 in	yards.	seconds.	
0									
100	0	6	0	10	1332	344	573	0·21	
200	0	15	0	20	1315	172	286	0·43	
300	0	25	0	31	1298	111	185	0·65	
400	0	35	0	42	1282	82	136	0·87	
500	0	45	0	53	1266	65	108	1·10	
600	0	56	1	4	1250	54	90	1·33	
700	1	7	1	16	1235	45	75	1·56	
800	1	18	1	28	1220	39	65	1·80	
900	1	29	1	40	1206	34	57	2·04	0·40
1000	1	40	1	53	1192	30	51	2·28	0·68
1100	1	51	2	6	1178	27	45	2·53	0·93
1200	2	2	2	19	1165	25	41	2·78	1·12
1300	2	14	2	33	1152	23	37	3·03	1·27
1400	2	24	2	47	1139	21	34	3·29	1·42
1500	2	38	3	1	1127	19	32	3·55	1·58
1600	2	50	3	16	1115	18	29	3·81	1·73
1700	3	2	3	31	1103	16	27	4·07	1·89
1800	3	15	3	46	1091	15	25	4·34	2·04
1900	3	27	4	2	1080	14	24	4·61	2·20
2000	3	40	4	18	1068	13	22	4·88	2·35
2100	3	53	4	34	1057	13	21	5·15	2·51
2200	4	6	4	51	1047	12	20	5·43	2·67
2300	4	19	5	8	1038	11	19	5·71	2·83
2400	4	33	5	25	1030	11	18	5·99	3·00
2500	4	47	5	43	1022	10	17	6·27	3·16
2600	5	1	6	1	1015	9·5	16	6·56	3·33
2700	5	15	6	20	1009	9·0	15	6·85	3·49
2800	5	29	6	39	1003	8·6	14	7·14	3·66
2900	5	44	6	58	997	8·2	14	7·43	3·83
3000	5	59	7	18	991	7·8	13	7·73	4·00
3100	6	14	7	38	984	7·5	12	8·03	4·17
3200	6	29	7	59	978	7·1	12	8·33	4·35
3300	6	45	8	20	972	6·8	11	8·63	4·52
3400	7	1	8	42	965	6·5	11	8·93	4·70
3500	7	17	9	4	959	6·3	10	9·24	4·88
3600	7	33	9	27	953	6·0	10	9·55	
3700	7	49	9	50	947	5·8	10	9·86	
3800	8	6	10	14	941	5·5	9	10·17	
3900	8	23	10	38	935	5·3	9	10·48	
4000	8	40	11	3	929	5·1	9	10·80	

Provisional Range Table for 9·2-inch B.L. Gun, Marks I. & II.*

Based on Calculation, checked by Practice of 2. and 22. 6. 85.†

Charge, 160 lb. Brown prism.[1] Gravimetric density, $\frac{80 \cdot 65}{9 \cdot 96}$
Projectile, weight 380 lb.
Muzzle velocity, 1835 f.s.
Mounting, Whitworth temporary.
Jump, 4 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Penetration, Wrought-Iron.	Fifty per cent. of Rounds should fall within			Time of Flight.	Estimated Fuse Scale for Armstrong Medium Time and Concussion Fuse, based on Practice of 2.6.85.	Fuse Scale for 15-Seconds Time and Percussion Fuze, based on Practice . .85.
							Length.	Breadth.	Height.			
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	feet	secs.		
0					1835	18·2						
100	0 1.	0 5	687	1146	1818	18·1	20	0·05	0·1	0·16		
200	0 6	0 10	343	573	1803	17·9	20	0·05	0·2	0·32		
300	0 11	0 15	229	382	1788	17·7	20	0·1	0·3	0·49		
400	0 16	0 21	164	275	1773	17·6	20	0·1	0·4	0·66		
500	0 21	0 26	132	220	1758	17·4	20	0·15	0·5	0·83		
600	0 27	0 32	107	179	1743	17·3	20	0·15	0·6	1·00		
700	0 32	0 38	90	151	1728	17·1	20	0·2	0·7	1·18		
800	0 38	0 44	78	130	1713	17·0	20	0·2	0·8	1·36		
900	0 43	0 50	69	115	1698	16·8	20	0·25	0·9	1·55		
1000	0 49	0 56	61	102	1683	16·6	20	0·3	1·0	1·71		
1100	0 55	1 2	55	92	1668	16·5	20	0·3	1·1	1·89		
1200	1 0	1 8	50	84	1654	16·4	20	0·35	1·2	2·07	0·55	
1300	1 6	1 15	46	77	1639	16·2	20	0·4	1·3	2·25	0·74	
1400	1 12	1 21	42	71	1624	16·0	20	0·4	1·5	2·44	0·93	
1500	1 18	1 28	39	65	1610	15·9	20	0·45	1·6	2·63	1·10	
1600	1 24	1 35	36	60	1595	15·7	20	0·45	1·7	2·82	1·24	
1700	1 30	1 42	34	56	1581	15·6	20	0·5	1·8	3·01	1·38	
1800	1 36	1 49	32	53	1567	15·4	20	0·55	1·9	3·20	1·52	
1900	1 42	1 56	30	49	1553	15·3	20	0·55	2·0	3·19	1·66	
2000	1 48	2 4	28	46	1539	15·1	20	0·6	2·2	3·59	1·79	
2100	1 54	2 12	26	43	1525	15 0	20	0·65	2·3	3·79	1·92	
2200	2 0	2 20	25	41	1512	14·8	20	0·65	2·5	3·99	2·06	
2300	2 6	2 28	23	39	1499	14·7	20	0·7	2·6	4·19	2·19	
2400	2 12	2 37	22	36	1486	14·5	20	0·75	2·8	4·39	2·32	
2500	2 19	2 46	21	34	1472	14·4	20	0·8	2·9	4·60	2·45	
2600	2 25	2 54	20	33	1459	14·2	20	0·8	3·1	4·81	2·58	
2700	2 32	3 3	19	31	1446	14·1	20	0·85	3·3	5·02	2·71	
2800	2 39	3 12	18	30	1433	13·9	21	0·9	3·5	5·23	2·84	
2900	2 46	3 20	17	28	1420	13·8	21	0·95	3·7	5·44	2·98	
3000	2 53	3 31	16	27	1408	13·6	21	1·0	3·9	5·65	3·12	
3100	3 0	3 41	16	26	1395	13·5	21	1·1	4·1	5·86	3·26	
3200	3 7	3 51	15	25	1383	13·4	21	1·1	4·3	6·08	3·40	
3300	3 14	4 2	14	24	1371	13·2	22	1·2	4·6	6·30	3·55	
3400	3 22	4 13	14	23	1359	13·1	22	1·2	4·9	6·25	3·70	
3500	3 29	4 24	13	22	1347	13·0	22	1·3	5·2	[illegible]·75	3·85	
3600	3 36	4 35	12	21	1335	12·8	23	1·3	5·6	6·97	4·00	
3700	3 44	4 46	12	20	1324	12·7	23	1·4	5·9	7·20	4·15	

PROVISIONAL RANGE TABLE FOR 9·2-INCH B.L. GUN, MARKS I. & II.— *continued.*

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Penetration, Wrought-Iron.	Fifty per cent. of Rounds should fall within Length.	Breadth.	Height.	Time of Flight.	Estimated Fuze Scale for Armstrong Medium Time and Concussion Fuze, based on Practice of 2.6.85.	Fuze Scale for 15-Seconds Time and Percussion Fuze, based on Practice . .85.
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	feet	secs.		
3800	3 51	4 58	12	19	1313	12·6	23	1·4	6·2	7·43	4·30	
3900	3 59	5 10	11	18	1302	12·5	24	1·5	6·5	7·66	4·45	
4000	4 7	5 22	11	18	1291	12·4	24	1·5	6·8	7·89	4·60	
4100	4 15	5 34	10	17	1280	12·3	24	1·6	7·2	8·12	4·75	
4200	4 23	5 46	9·9	17	1269	12·1	25	1·7	7·5	8·36	4·90	
4300	4 31	5 58	9·6	16	1258	12·0	25	1·7	7·8	8·60		
4400	4 39	6 10	9·3	16	1247	11·9	25	1·8	8·2	8·64		
4500	4 48	6 23	9·0	15	1237	11·8	26	1·9	8·6	9·08		
4600	4 56	6 36	8·7	15	1227	11·7	26	1·9	9·0	9·33		
4700	5 5	6 49	8·4	14	1217	11·5	26	2·0	9·5	9·58		
4800	5 14	7 2	8·2	14	1207	11·4	27	2·1	10	9·82		
4900	5 23	7 16	7·9	14	1198	11·3	27	2·2	10	10·05		
5000	5 32	7 30	7·7	13	1188	11·2	27	2·2	11	10·3		
5100	5 41	7 44	7·4	12	1179	11·1	27	2·3	11	10·55		
5200	5 50	7 59	7·2	12	1170	11·0	28	2·4	11	10·8		
5300	6 0	8 14	7·0	12	1161	10·9	28	2·5	12	11·1		
5400	6 9	8 30	6·8	11	1152	10·9	28	2·5	13	11·35		
5500	6 19	8 46	6·6	11	1143	10·8	28	2·6	13	11·6		
5600	6 29	9 2	6·4	11	1135	10·7	29	2·7	14	11·85		
5700	6 39	9 18	6·2	10	1127	10·6	29	2·8	14	12·15		
5800	6 49	9 34	6·0	10	1119	10·5	29	2·9	14	12·4		
5900	6 59	9 51	5·8	10	1111	10·5	29	3·0	15	12·65		
6000	7 9	10 8	5·7	9	1103	10·4	30	3·1	15	12·95		
6100	7 20	10 25	5·4	9	1095	10·3				13·2		
6200	7 30	10 42	5·3	9	1088	10·2				13·5		
6300	7 40	11 0	5·1	9	1081	10·2				13·8		
6400	7 51	11 18	5·0	8	1074	10·1				14·1		
6500	8 1	11 36	4·9	8	1067	10·0				14·3		
6600	8 12	11 54	4·7	8	1060	10·0				14·6		
6700	8 23	12 13	4·6	8	1054	9·9				14·9		
6800	8 34	12 32	4·5	7	1048	9·8				15·2		
6900	8 45	12 51	4·4	7	1042	9·8				15·4		
7000	8 56	13 10	4·3	7	1037	9·7				15·7		
7100	9 8	13 30	4·2	7	1032	9·6				16·0		
7200	9 19	13 50	4·1	7	1027	9·6				16·3		
7300	9 30	14 10	4·0	7	1022	9·5				16·6		
7400	9 42	14 31	3·9	6	1017	9·5				16·9		
7500	9 54	14 52	3·8	6	1013	9·4				17·2		
7600	10 6	15 13	3·7	6	1008	9·4				17·5		
7700	10 18	15 34	3·6	6	1004	9·3				17·8		
7800	10 30	15 55	3·5	6	999	9·3				18·1		
7900	10 42	16 17	3·4	6	995	9·3				18·4		
8000	10 54	16 39	3·3	6	991	9·2				18·7		

* The Table is provisional, pending practice up to 15 degrees elevation. The practice on which it is based extended up to 6000 yards only.

† This practice took place before the gun was reduced in length by 1 calibre, calculation has therefore to be resorted to.

Range Table for 12-inch B.L. Gun, Marks I, II, III, and IV.

Based on Practice of 24. and 25. 2. 85., 17. 4. 85., and 23. 6. 85., also (from 6,000 to 8,000 yards) on Calculation.

Charge, 295 lb. brown prism.[1].
Gravimetric density, $\frac{33 \cdot 1}{0 \cdot 838}$.
Projectile, weight 714 lb.
Muzzle velocity, 1892 f.s.
Mounting, garrison "yoke."
Jump, 6 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an Object 10 feet high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	Fifty per Cent. of Rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Estimated Fuze Scale for Armstrong medium Time and Concussion Fuze, based on Practice with 195 and 280 lb. charges.	Fuze Scale for 15-secs. Time and Percussion Fuze, based on Practice 23. 6. 85.
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	feet.	secs.		
0					1892	22·5						
100		0 5	688	1146	1876	22·3	18	0·05	0·1	0·16		1·0
200	0 4	0 10	344	573	1860	22·1	18	0·05	0·2	0·32		1·8
300	0 9	0 15	229	382	1845	21·9	18	0·1	0·3	0·48		2·6
400	0 13	0 20	172	286	1829	21·7	18	0·1	0·3	0·64		3·35
500	0 18	0 25	137	229	1814	21·5	18	0·1	0·4	0·81		4·1
600	0 23	0 30	114	190	1799	21·3	18	0·15	0·5	0·98		4·8
700	0 28	0 36	96	160	1784	21·1	18	0·15	0·6	1·15		5·45
800	0 33	0 41	84	140	1769	20·9	18	0·2	0·6	1·32		6·05
900	0 38	0 46	75	125	1754	20·7	18	0·2	0·7	1·59		6·7
1000	0 44	0 52	66	110	1739	20·5	18	0·2	0·8	1·66		7·3
1100	0 49	0 58	59	99	1725	20·3	18	0·25	0·9	1·83	0·45	7·9
1200	0 54	1 4	54	90	1710	20·1	18	0·25	1·0	2·01	0·63	8·45
1300	1 0	1 10	49	82	1696	19·9	18	0·3	1·1	2·18	0·81	9·05
1400	1 5	1 16	45	75	1681	19·8	18	0·3	1·2	2·36	0·98	9·65
1500	1 10	1 23	41	69	1667	19·6	18	0·35	1·3	2·54	1·14	10·2
1600	1 16	1 29	39	64	1653	19·4	18	0·35	1·4	2·72	1·28	10·8
1700	1 21	1 36	36	60	1639	19·2	18	0·4	1·5	2·90	1·42	11·35
1800	1 27	1 43	33	56	1625	19·0	18	0·4	1·6	3·09	1·55	11·95
1900	1 32	1 50	31	52	1611	18·8	18	0·45	1·7	3·28	1·69	12·5
2000	1 38	1 57	29	49	1597	18·7	18	0·45	1·8	3·47	1·52	13·1
2100	1 44	2 4	28	46	1583	18·5	18	0·5	1·9	3·66	1·95	13·65
2200	1 50	2 11	26	44	1570	18·3	18	0·5	2·0	3·85	2·08	14·2
2300	1 56	2 19	25	41	1556	18·1	18	0·55	2·2	4·04	2·21	14·8
2400	2 2	2 27	23	39	1543	18 0	18	0·55	2·3	4·23	2·34	15·3
2500	2 9	2 35	22	37	1530	17·8	18	0·6	2·4	4·43	2·47	15·9
2600	2 15	2 43	21	35	1517	17·6	18	0·6	2·5	4·63	2·60	16·4
2700	2 21	2 51	20	33	1504	17·5	18	0·65	2·7	4·83	2·73	17·0
2800	2 28	2 59	19	32	1491	17·3	18	0·65	2·8	5·03	2·86	17·6
2900	2 34	3 8	18	30	1478	17·2	18	0·7	3·0	5·23	3·0	18·2
3000	2 40	3 17	17	29	1465	17·0	18	0·75	3·1	5·44	3·14	18·8
3100	2 47	3 26	17	28	1452	16·8	18	0·75	3·3	5·65	3·28	19·3
3200	2 54	3 35	16	27	1440	16·7	18	0·8	3·5	5·86	3·42	19·8
3300	3 0	3 44	15	26	1427	16·5	19	0·85	3·7	6·07	3·56	20·4
3400	3 7	3 54	15	25	1415	16·3	19	0·85	3·9	6·28	3·70	21·0
3500	3 14	4 4	14	24	1403	16·2	19	0·9	4·1	6·50	3·85	21·6
3600	3 21	4 14	14	23	1391	16·1	19	0·95	4·3	6·72	4·00	22·2

Range Table for 12-inch B.L. Gun, Marks I, II, III, and IV.—*contd.*

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an Object 10 feet high, Range must be known within	Remaining Velocity.	Penetration, Wrought Iron.	Fifty per Cent. of Rounds should fall within: Length.	Breadth.	Height.	Time of Flight.	Estimated Fuze Scale for Armstrong medium Time and Concussion Fuze, based on Practice with 195 and 260 lb. charges.	Fuze Scale for 15 secs. Time and Percussion Fuze, based on Practice 23. 6. 85.
yds.	° ′	° ′	1 in	yds.	f.s.	ins.	yds.	yds.	feet.	secs.		
3700	3 28	4 24	13	22	1379	15·9	19	1·0	4·5	6·94	4·15	22·7
3800	3 36	4 35	12	21	1368	15·7	19	1·1	4·7	7·16	4·30	23·3
3900	3 43	4 46	12	20	1356	15·6	19	1·1	4·9	7·38	4·45	23·9
4000	3 50	4 58	12	19	1345	15·4	20	1·2	5·1	7·61	4·60	24·5
4100	3 57	5 9	11	18	1334	15·3	20	1·2	5·4	7·84	4·75	25·1
4200	4 5	5 21	11	18	1323	15·1	20	1·3	5·6	8·07	4·90	25·7
4300	4 12	5 33	10	17	1312	15·0	20	1·4	5·9	8·30		26·3
4400	4 20	5 45	9·9	17	1301	14·8	20	1·4	6·2	8·54		26·9
4500	4 28	5 57	9·6	16	1290	14·7	21	1·5	6·4	8·78		27·5
4600	4 35	6 9	9·3	15	1280	14·6	21	1·6	6·7	9·02		28·2
4700	4 43	6 21	9·0	15	1269	14·4	21	1·6	7·0	9·26		28·8
4800	4 51	6 34	8·7	14	1259	14·3	21	1·7	7·3	9·50		29·4
4900	4 59	6 46	8·4	14	1249	14·2	22	1·8	7·6	9·75		30·0
5000	5 7	6 59	8·2	14	1239	14·1	22	1·9	8·0	10·0		
5100	5 16	7 11	7·9	13	1230	13·9	22	2·0	8·3	10·3		
5200	5 24	7 24	7·7	13	1221	13·8	23	2·1	8·7	10·5		
5300	5 32	7 37	7·5	12	1211	13·7	23	2·2	9·1	10·8		
5400	5 41	7 50	7·3	12	1202	13·6	23	2·3	9·5	11·0		
5500	5 49	8 4	7·1	12	1193	13·5	23	2·4	9·9	11·3		
5600	5 58	8 17	6·9	11	1184	13·3	24	2·5	10·3	11·6		
5700	6 7	8 31	6·7	11	1175	13·2	24	2·7	10·7	11·8		
5800	6 16	8 45	6·5	11	1167	13·1	24	2·8	11·2	12·1		
5900	6 25	8 59	6·3	11	1158	13·0	24	2·9	11·6	12·3		
6000	6 34	9 13	6·2	10	1150	12·9	25	3·0	12·0	12·6		
6100	6 44	9 28	6·0	10	1142	12·8				12·9		
6200	6 53	9 43	5·8	10	1134	12·7				13·1		
6300	7 2	9 58	5·7	9	1126	12·6				13·4		
6400	7 11	10 14	5·6	9	1118	12·5				13·7		
6500	7 21	10 30	5·4	9	1110	12·4				14·0		
6600	7 30	10 46	5·3	9	1103	12·3				14·3		
6700	7 39	11 2	5·1	9	1095	12·2				14·5		
6800	7 49	11 18	5·0	8	1088	12·1				14·8		
6900	7 59	11 35	4·9	8	1081	12·0				15·1		
7000	8 9	11 52	4·8	8	1074	11·9				15·4		
7100	8 19	12 9	4·6	8	1068	11·8				15·7		
7200	8 30	12 27	4·5	8	1062	11·8				16·0		
7300	8 40	12 45	4·4	7	1056	11·7				16·3		
7400	8 51	13 3	4·3	7	1050	11·6				16·6		
7500	9 2	13 22	4·2	7	1045	11·6				16·8		
7600	9 12	13 41	4·1	7	1040	11·5				17·1		
7700	9 23	14 0	4·0	7	1035	11·4				17·4		
7800	9 34	14 20	3·9	7	1030	11·4				17·7		
7900	9 45	14 40	3·8	6	1025	11·3				18·0		
8000	9 57	15 0	3·7	6	1021	11·2				18·3		

(C.O.) 2 I

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Range Table for 12-inch B. L. Gun, Marks I, II, III, or IV.

Based on Practice of 18. 6. 84.

Charge, 221¼ brown prism; gravimetric density, $\frac{44 \cdot 1}{0 \cdot 623}$

Projectile, weight, 714 lb.

Mounting, Garrison yoke.

Muzzle velocity, 1613 f.s.

Jump, 7 minutes.

Range.	Elevation.	Angle of Descent.	Slope of Descent.	To hit an object 10 feet high, Range must be known within	Remaining Velocity.	Time of Flight.	Estimated Fuze Scale.—Armstrong medium time and concussion fuze, based on practice with 160 and 196 lb. charges.
yards.	° ′	° ′	1 in	yards.	f.s.	seconds.	
0					1613		
100		0 7	491	809	1590	0·19	
200	0 6	0 13	264	404	1585	0·38	
300	0 12	0 20	172	290	1572	0·57	
400	0 19	0 27	127	212	1558	0·76	
500	0 26	0 34	101	169	1545	0·95	
600	0 33	0 42	82	136	1532	1·15	
700	0 40	0 49	70	117	1519	1·35	
800	0 48	0 57	60	101	1506	1·55	
900	0 55	1 5	53	88	1493	1·75	
1000	1 2	1 13	47	78	1480	1·96	
1100	1 9	1 21	42	71	1467	2·17	0·60
1200	1 17	1 29	39	64	1454	2·38	0·84
1300	1 24	1 38	35	58	1442	2·59	1·04
1400	1 31	1 46	32	54	1429	2·80	1·21
1500	1 39	1 55	30	50	1417	3·01	1·38
1600	1 47	2 3	28	46	1405	3·22	1·54
1700	1 54	2 12	26	43	1393	3·44	1·71
1800	2 2	2 22	24	40	1381	3·66	1·87
1900	2 10	2 31	23	38	1370	3·88	2·03
2000	2 18	2 41	21	36	1358	4·10	2·19
2100	2 27	2 51	20	33	1347	4·33	2·34
2200	2 35	3 1	19	31	1336	4·56	2·50
2300	2 43	3 12	18	30	1325	4·79	2·65
2400	2 52	3 23	17	28	1314	5·02	2·81
2500	3 0	3 34	16	27	1303	5·26	2·96
2600	3 9	3 45	15	25	1292	5·50	3·11
2700	3 18	3 57	14	24	1282	5·74	3·26
2800	3 27	4 9	14	23	1271	5·98	3·41
2900	3 36	4 21	13	22	1261	6·22	3·56
3000	3 45	4 34	13	21	1251	6·46	3·71
3100	3 54	4 46	12	20	1241	6·71	3·86
3200	4 3	4 59	11	19	1232	6·95	4·01
3300	4 13	5 12	11	18	1223	7·20	4·17
3400	4 22	5 25	11	18	1213	7·45	4·32
3500	4 32	5 39	10	17	1204	7·70	4·48
3600	4 41	5 53	9·7	16	1195	7·95	4·63
3700	4 51	6 7	9·3	16	1186	8·20	4·79
3800	5 1	6 21	9·0	15	1177	8·45	4·94
3900	5 11	6 35	8·7	14	1168	8·71	
4000	5 21	6 51	8·3	14	1159	8·97	
4100	5 31	7 6	8·0	13	1151	9·23	
4200	5 41	7 22	7·7	13	1143	9·49	
4300	5 51	7 38	7·5	12	1135	9·76	
4400	6 2	7 54	7·2	12	1127	10·03	
4500	6 12	8 10	7·0	12	1119	10·30	
4600	6 33	8 27	6·7	11	1111	10·58	
4700	6 34	8 44	6·5	11	1104	10·86	
4800	6 45	9 1	6·3	10	1096	11·14	
4900	6 56	9 18	6·1	10	1089	11·42	
5000	7 7	9 36	5·9	10	1082	11·71	

Note.—Up to about 2000 yards range the accuracy on a vertical target with this charge may be considered equal to that with the full charge; at longer ranges it will probably be from 10 to 30 per cent. inferior.

RANGE TABLE FOR 13·5-INCH B.L. GUN OF 68 AND 66 TONS.

Charge, , Density, .
Projectile, .
M.V., f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.		Range.	Elevation.	Time of Flight.	Fuze Scale.	
			Range.	Tenths.				Range.	Tenths.
Yards.	° ′	″			Yards.	° ″	″		

RANGE TABLE FOR 16·25-INCH B.L. GUN OF 110 TONS.

Charge, . Density, .
Projectile, .
M.V., f.s.

Range.	Elevation.	Time of Flight.	Fuze Scale.		Range.	Elevation.	Time of Flight.	Fuze Scale.	
			Range.	Tenths.				Range.	Tenths.
Yards.	° ′	″			Yards.	° ′	″		

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12 Pr. B. L. GUN. 7 CWT. MARK I.

SCALE $\frac{1}{16}$.

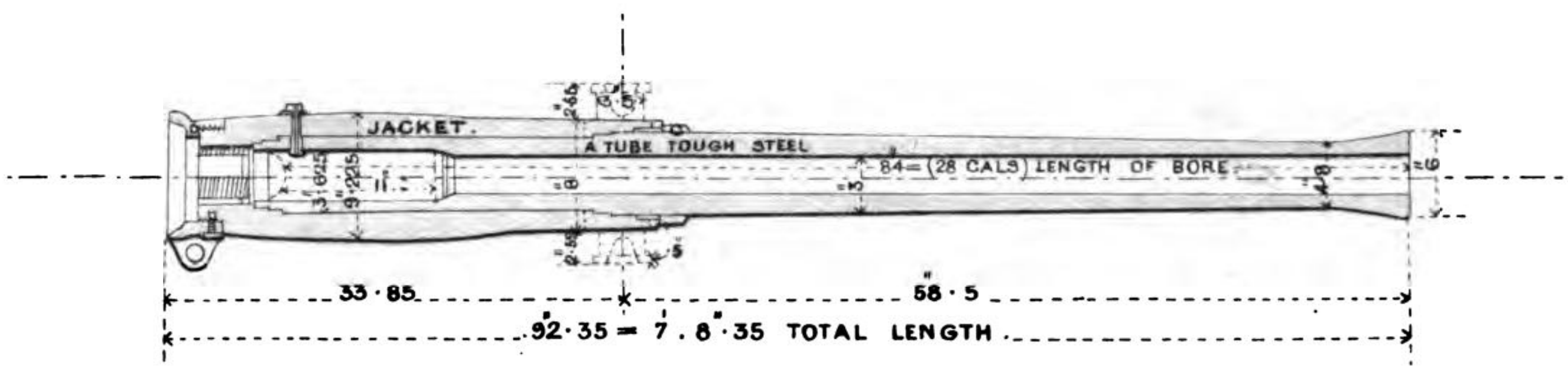

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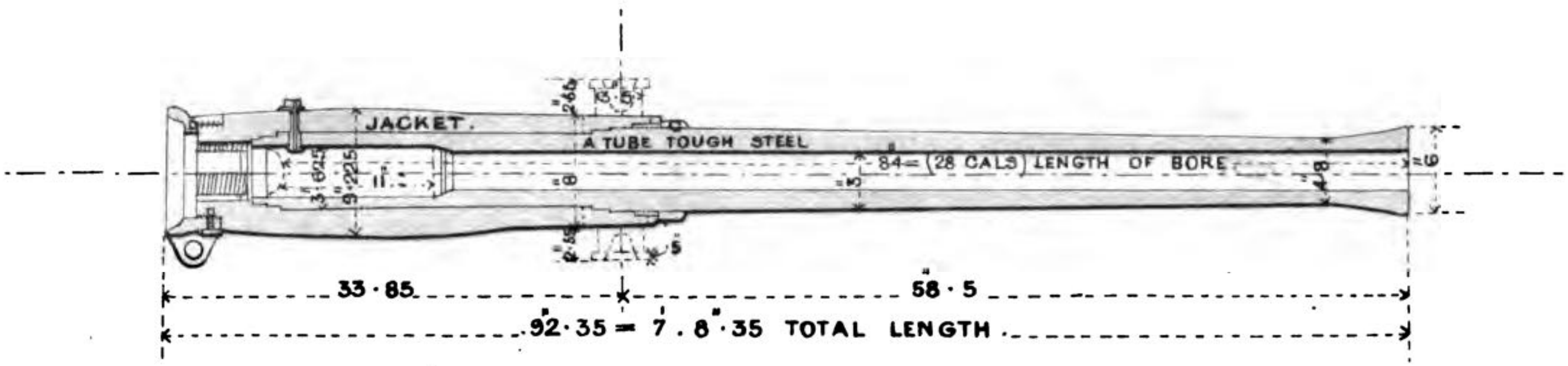
Plate I

12 Pr. B.L. GUN. 7 CWT. MARK I.

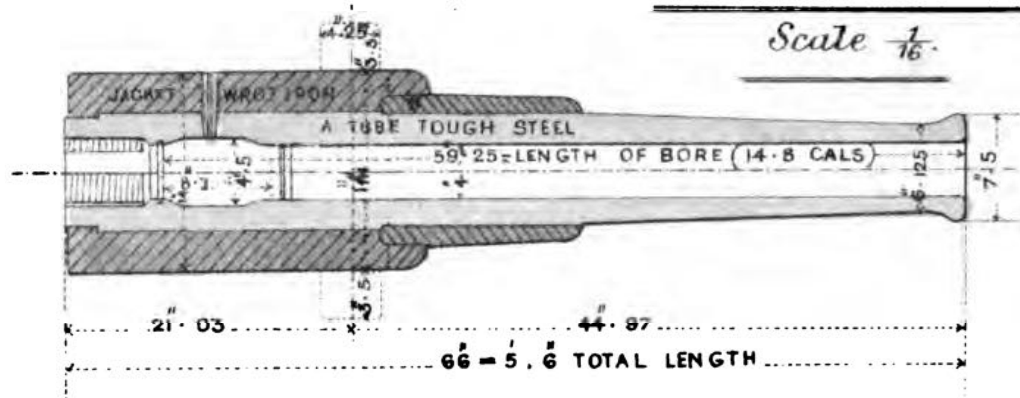
SCALE $\frac{1}{16}$.



DANGERFIELD. LITH 22 BEDFORD ST. COVENT GARDEN 7973.

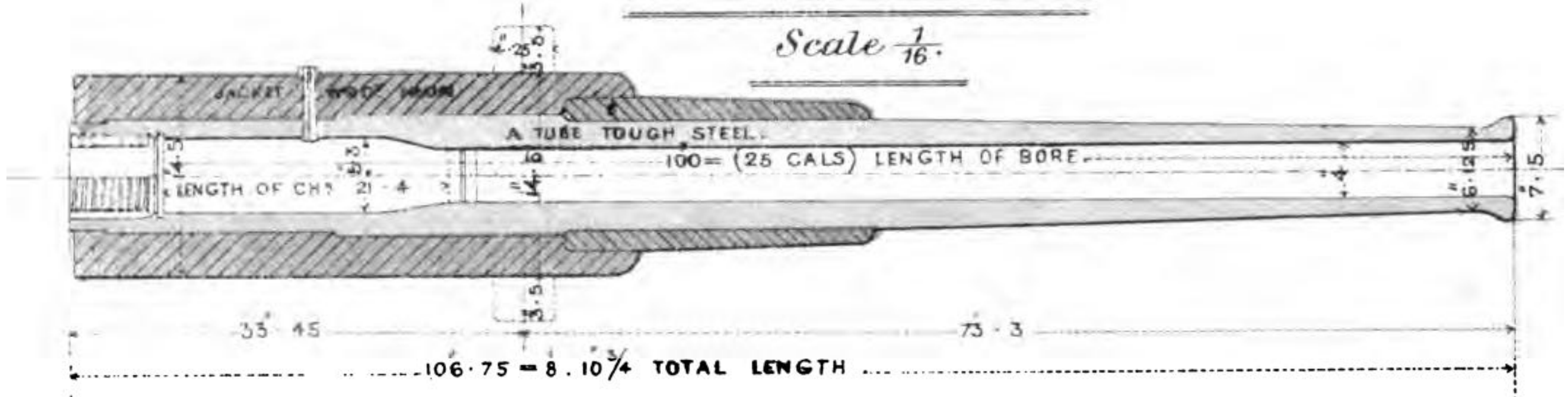
4 In. B. L. Gun. 13 Cwt. Mark I.

Scale $\frac{1}{16}$.



4 In. B. L. Gun. 22 Cwt Mark I.

Scale $\frac{1}{16}$.

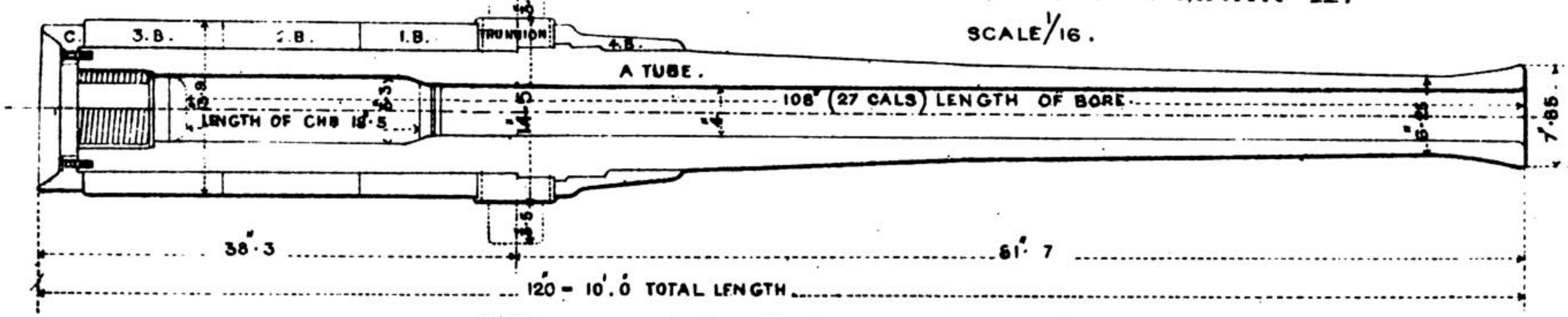


Dangerfield, Lith 22 Bedford S.t Covent Garden 7974

Plate III.

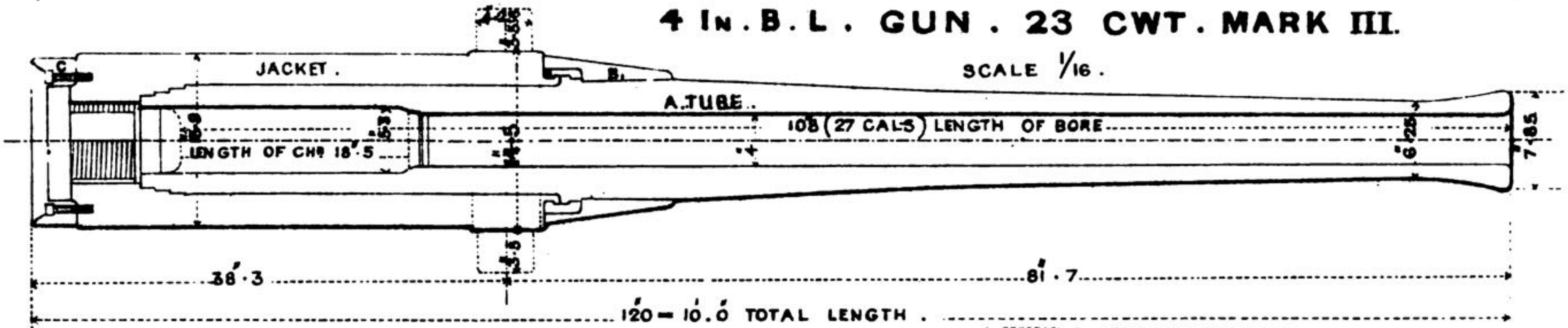
4 In. B.L. Gun. 23 Cwt. Mark II.

Scale 1/16.



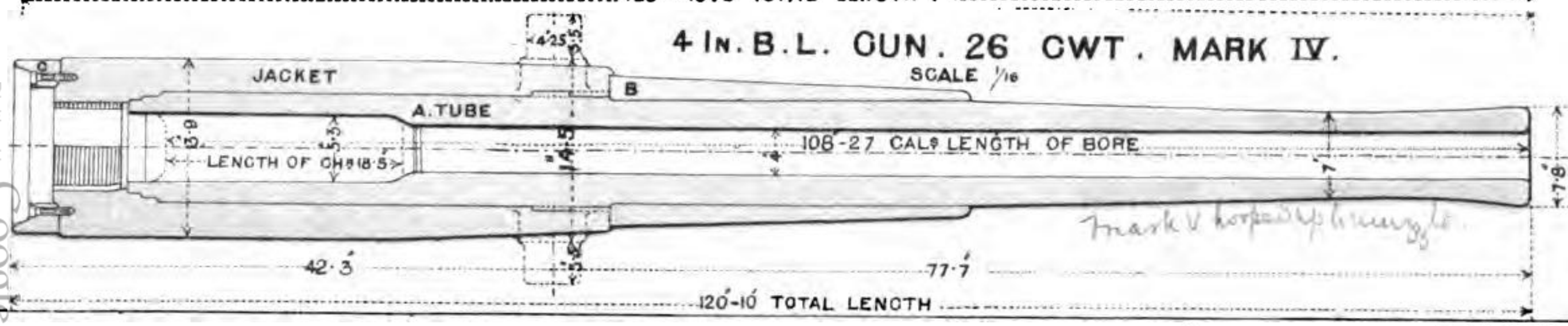
4 In. B.L. Gun. 23 Cwt. Mark III.

Scale 1/16.

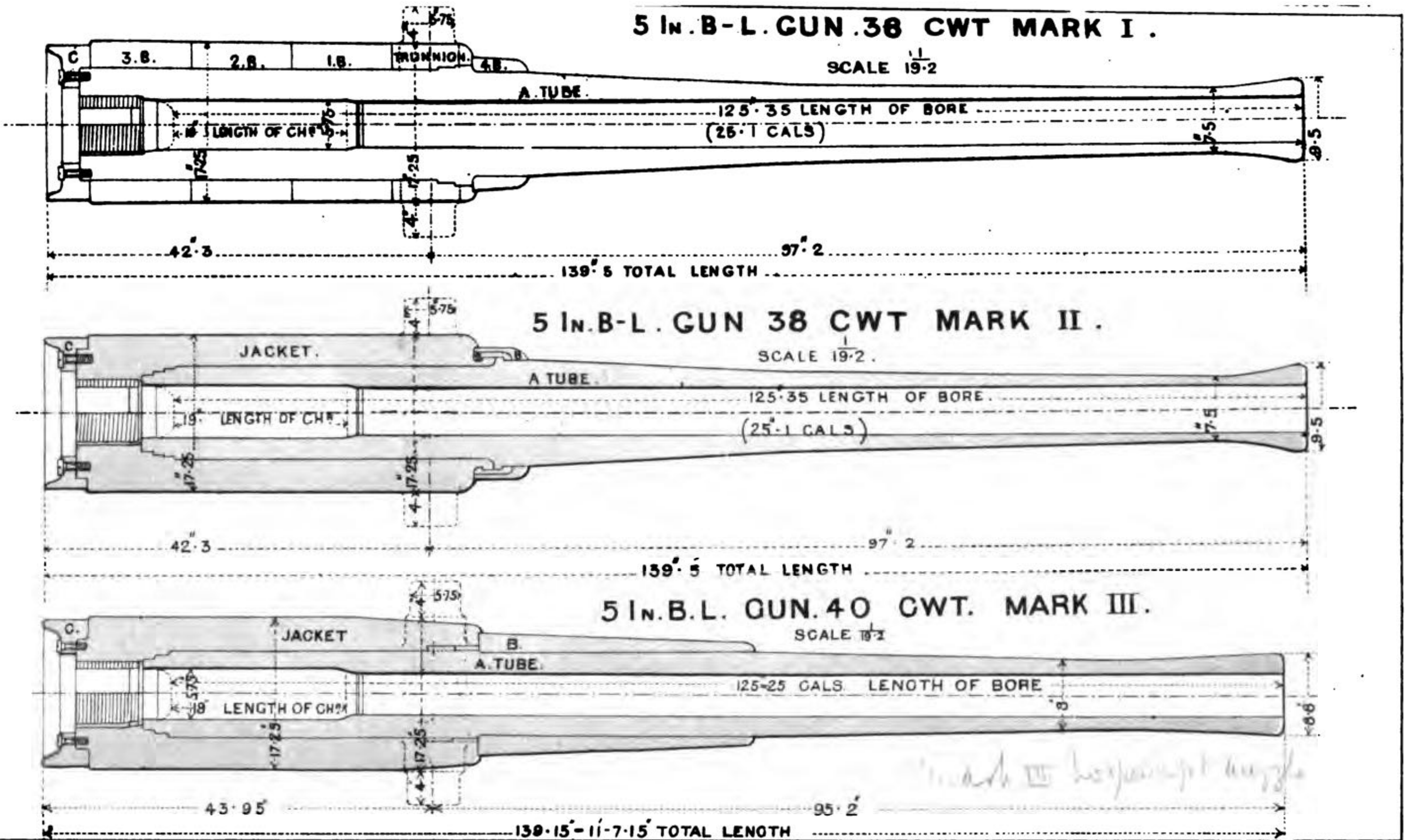


4 In. B.L. Gun. 26 Cwt. Mark IV.

Scale 1/16

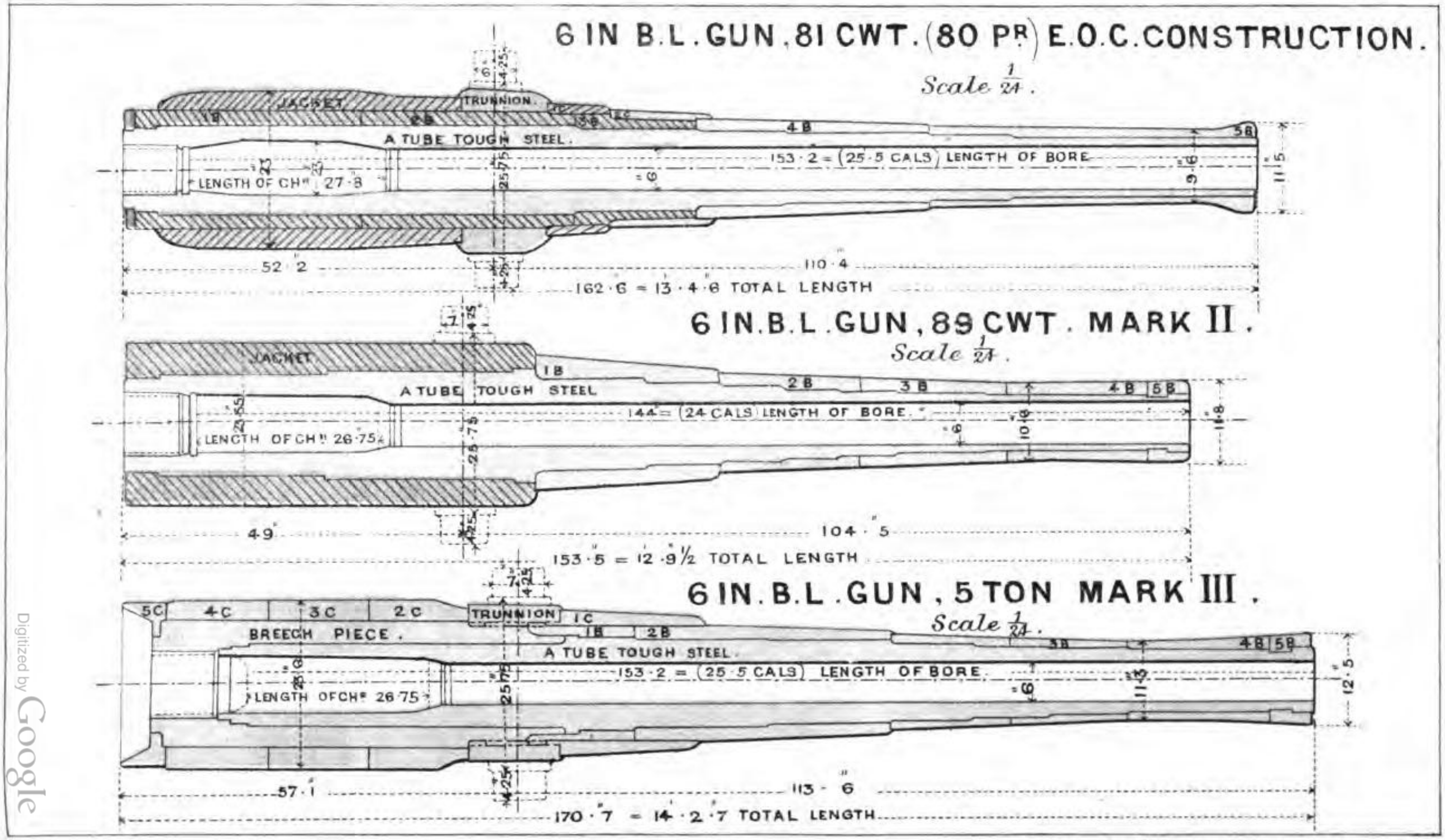


Dangerfield. Lith. 22, Bedford St. Covent Garden 797.



7973

Dangerfield, Lith. 22, Bedford St Covent Garden

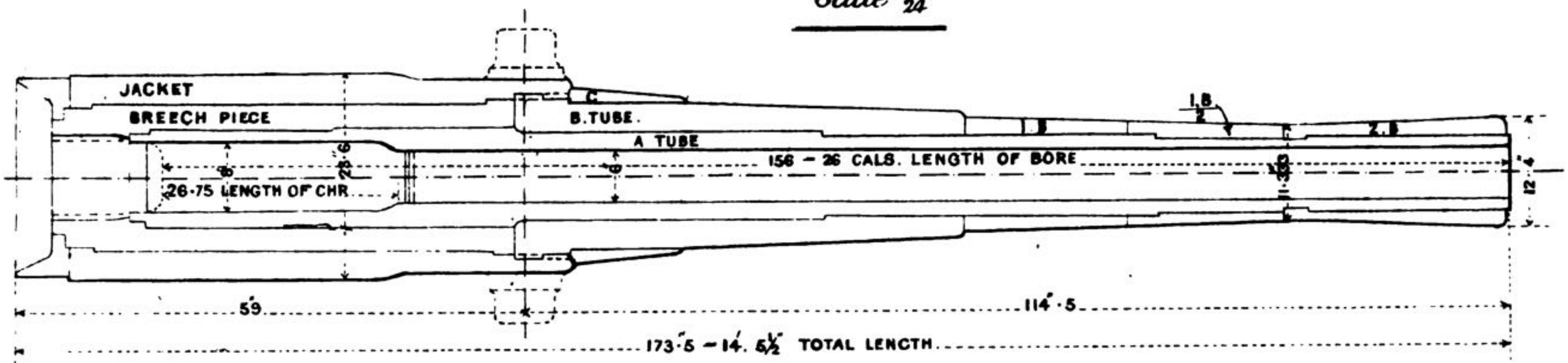


DANGERFIELD, LITH. 22, BEDFORD ST COVENT GARDEN 7974.

Plate VI.

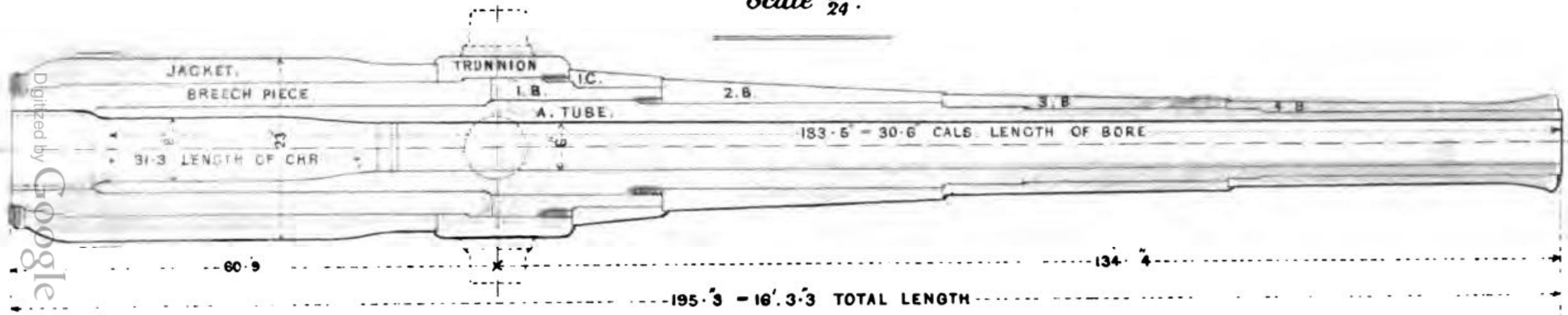
6 IN B.L. GUN 5 TON. MARK IV.

Scale $\frac{1}{24}$



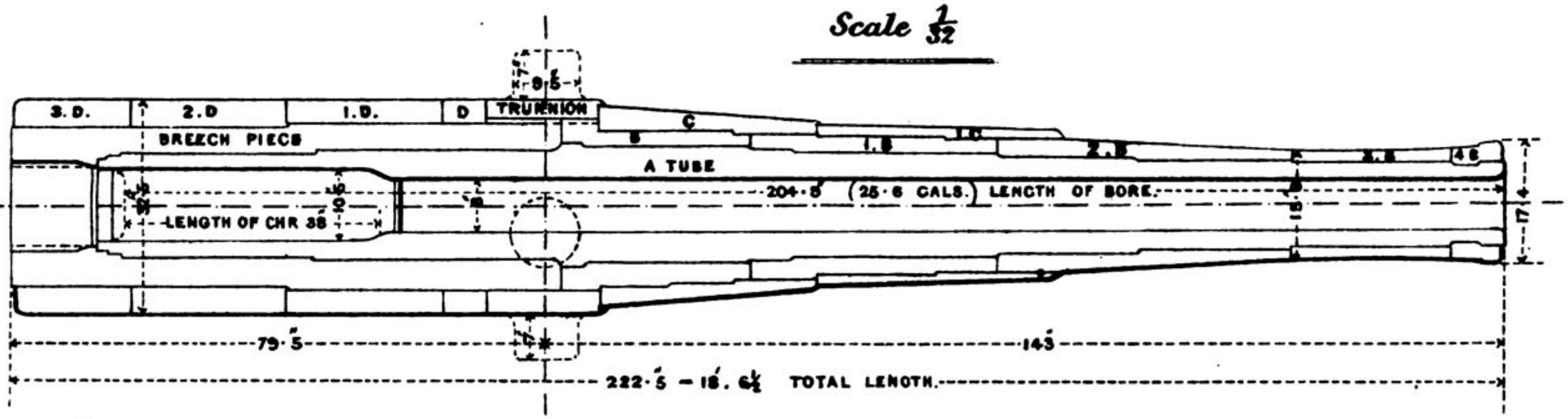
6 IN B.L. GUN 5 TON. MARK V. E.O.C. CONSTRUCTION.

Scale $\frac{1}{24}$.



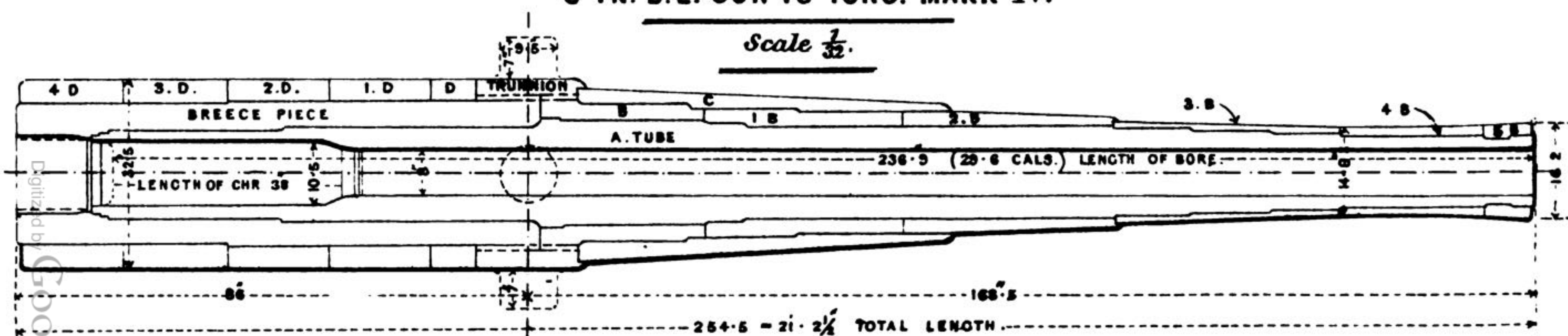
8 IN. B.L. GUN 14 TONS. MARK III.

Scale $\frac{1}{32}$



8 IN. B.L. GUN 15 TONS. MARK IV.

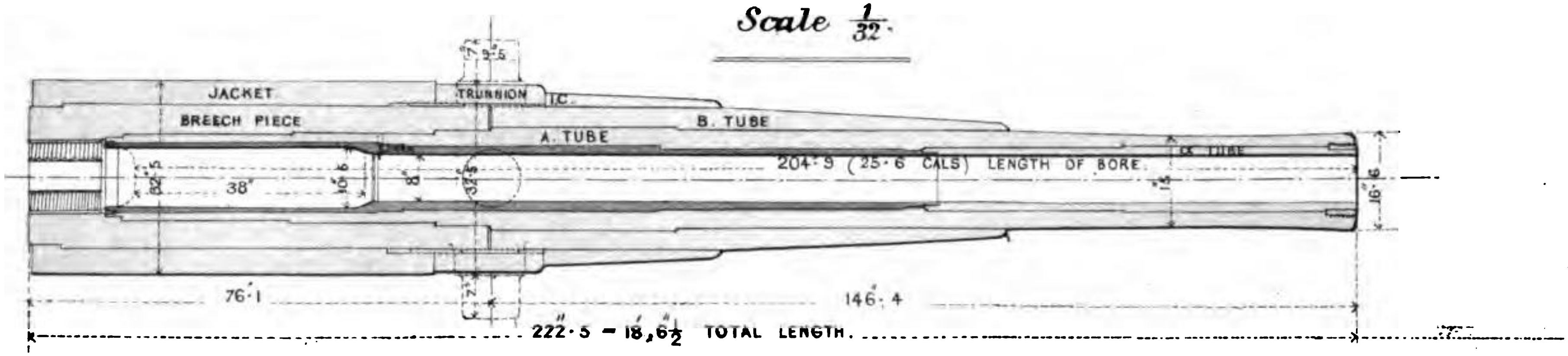
Scale $\frac{1}{32}$.



DANGERFIELD LITH.

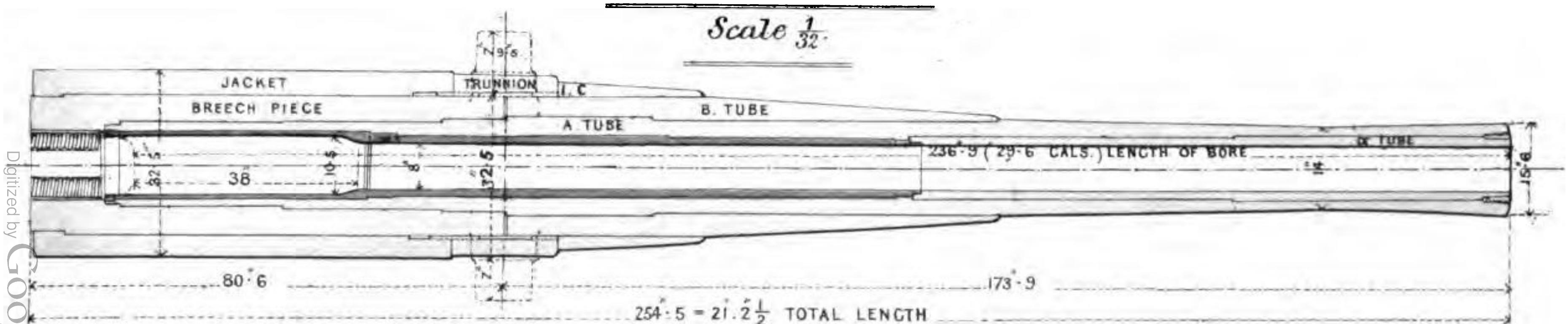
8 IN. B. L. GUN 13 TONS MARK V.

Scale $\frac{1}{32}$.



8 IN B. L. GUN 14 TONS MARK VI.

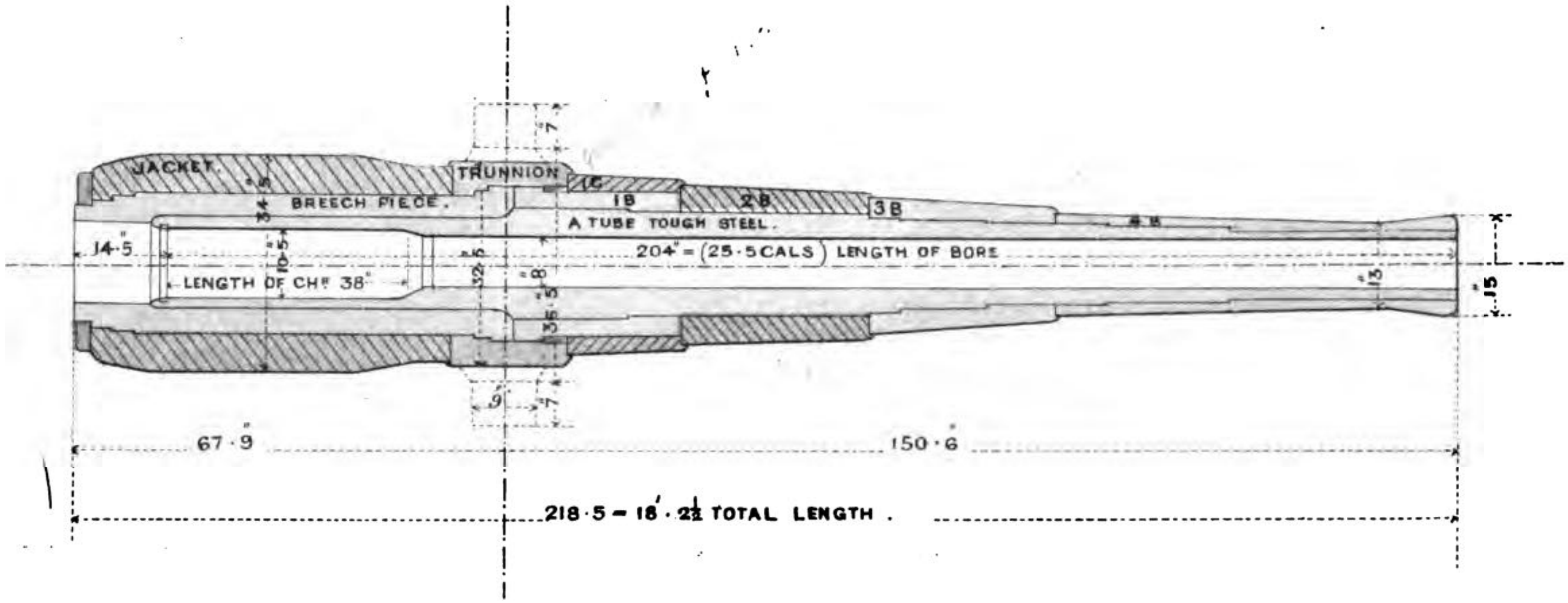
Scale $\frac{1}{32}$.



DANGERFIELD, LITH. 22. BEDFORD ST COVENT GARDEN. 7974

8 INCH. B.L. GUN 12 TONS MARK VII E.O.C. CONSTRUCTION.

Scale $\frac{1}{32}$.

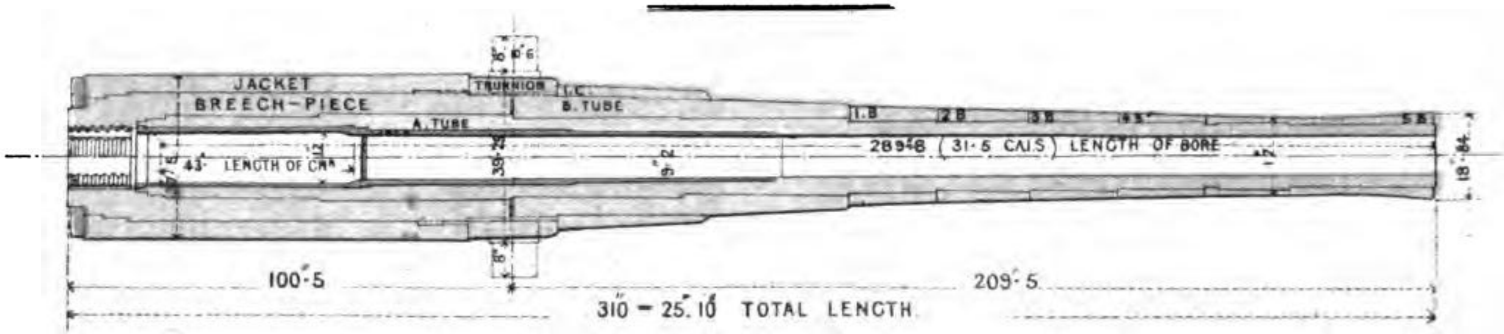


DANGERFIELD, LITH. 22, BEDFORD S^T COVENT GARDEN 7874.

Plate X.

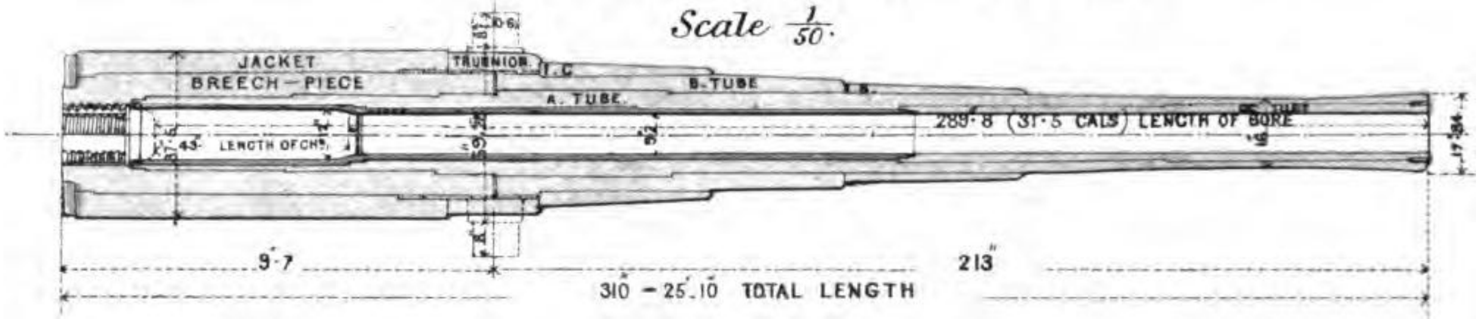
9·2 IN. B. L. GUN 23 TONS. MARK IV.

Scale 1/50



9·2 IN. B. L. GUN. 22 TONS. MARK V.

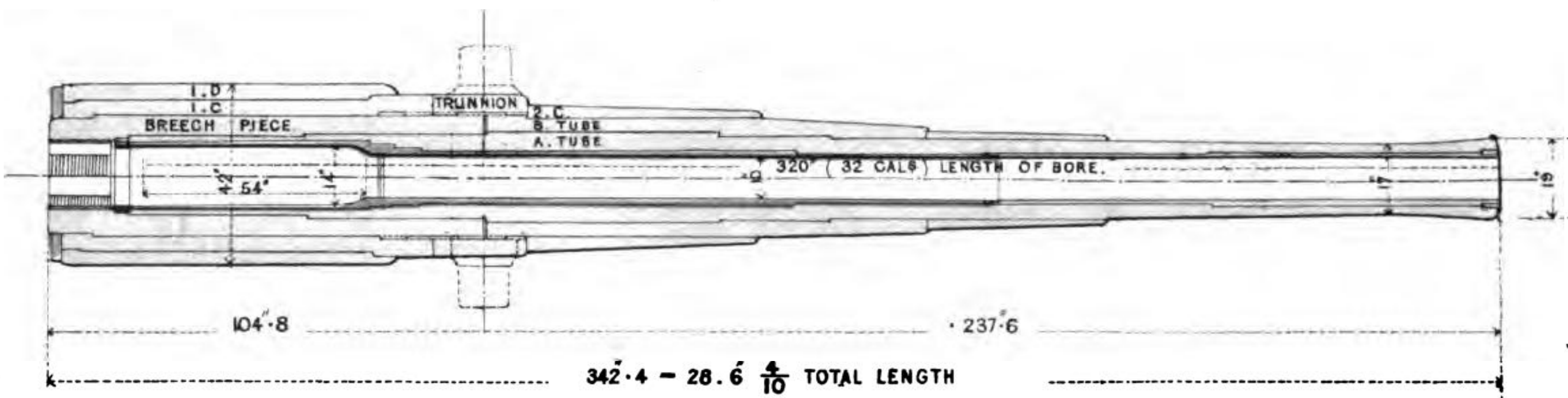
Scale 1/50.



DANGERFIELD, LITH. 22, BEDFORD ST. COVENT GARDEN 7974

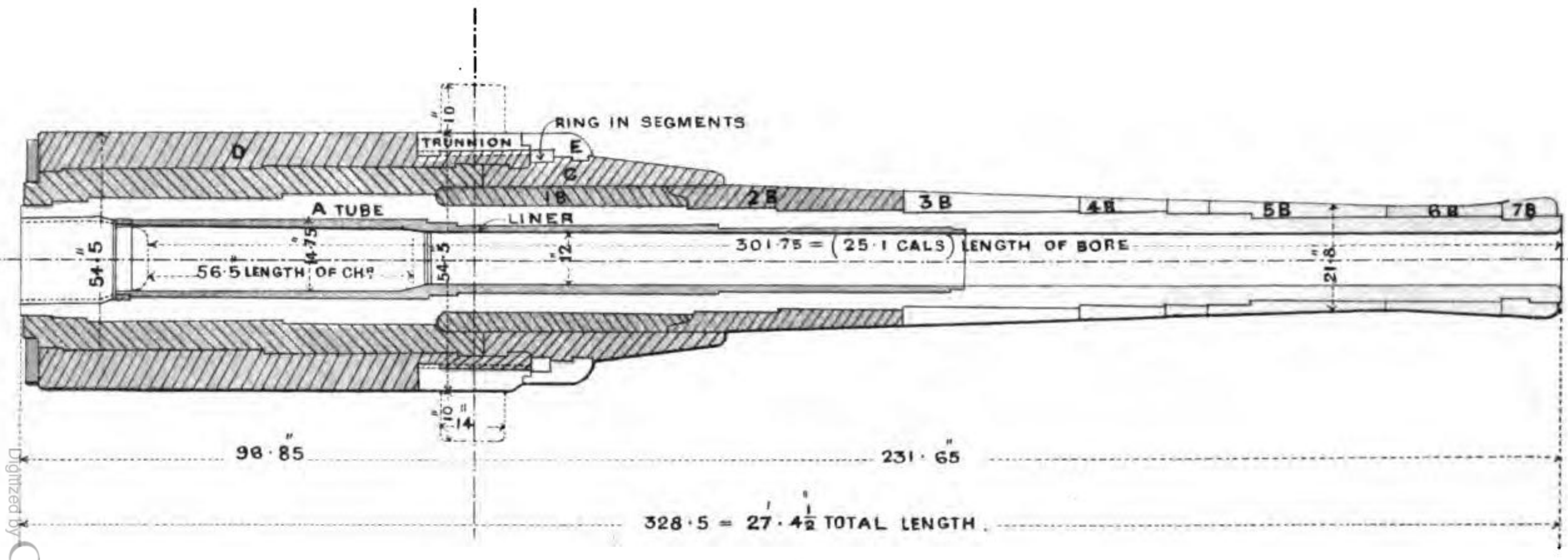
10 IN B.L. GUN 29 TON. MARK II.

Scale $\frac{1}{48}$.



12 INCH . B.L . GUN 47 TONS MARK I .

Scale 1/40 .

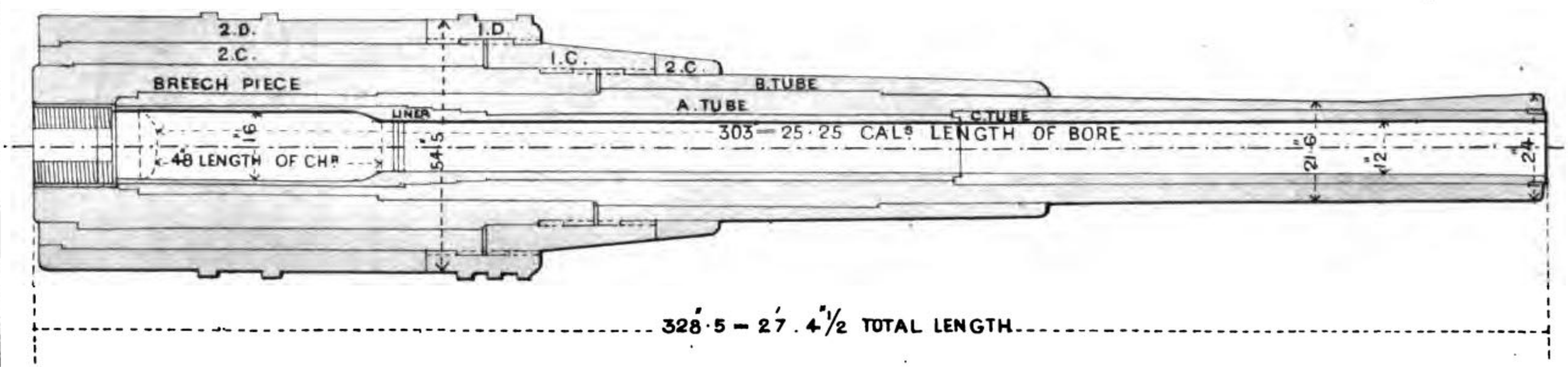


DANGERFIELD, LITH. 22, BEDFORD ST COVENT GARDEN 7874.

ORDNANCE. B. L. 12 INCH. (MARK V.)

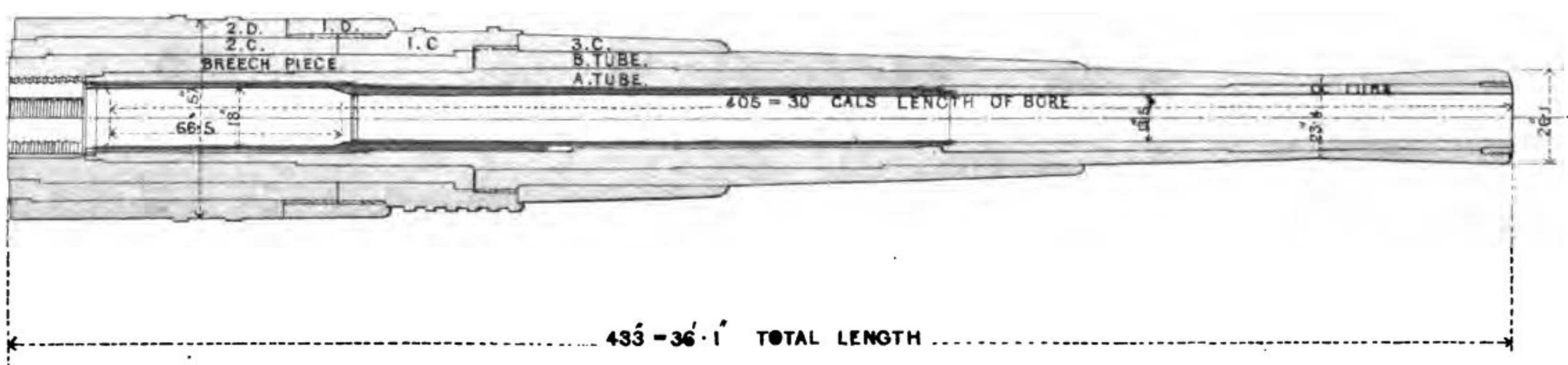
STEEL 45 TON.

SCALE $\frac{1}{40}$.



13·5 IN. B.L. GUN, 67 TONS. MARK II.

Scale $\frac{1}{60}$.

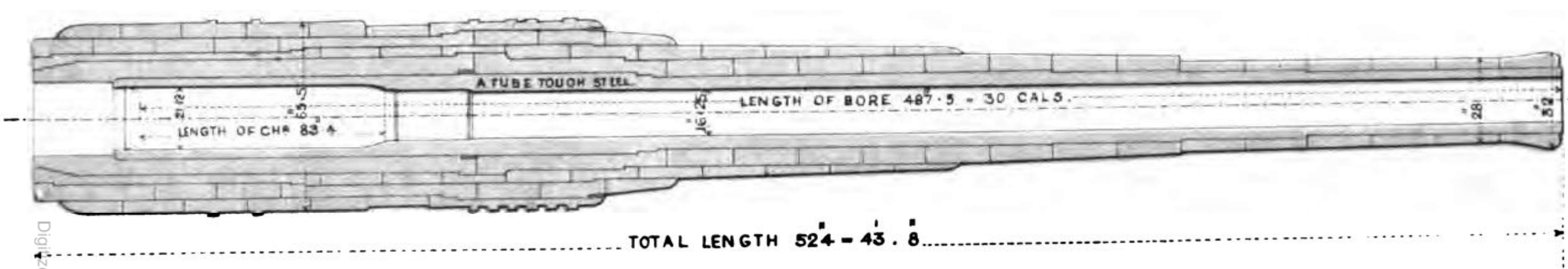


DANGERFIELD, LITH. 22, BEDFORD ST. COVENT GARDEN. 7374

16·25 In. B. L. GUN 111 TONS.

Scale $\frac{1}{68}$

E.O.C. CONSTRUCTION.



DANGERFIELD LITH 22 BEDFORD ST COVENT GARDEN 7873.

~~2 ... app~~ ... 1/4 ... traction

Questions to be considered on gun construction

1. Material
2. Construction
3. Design
4. ... breech loading
5. rifling
6. firing arrangements
7. ...

8. ... other details

Diff parts of R.G. F R M L Gun

breech piece
barrel
... coil ... front of trunnion
... coils ... chase
jacket
cascable ... breech

phosphorus makes cast iron brittle when cold.
Sulphur ... hot

Silicon ... steel from blowholes
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